# Iron and Steel ENGINEER

ENGINEERING SERVICE
TO THE IRON AND STEEL
INDUSTRY SINCE 1907

1010 EMPIRE BUILDING

DECEMBER, 1942

PITTSBURGH, PA.

PUBLIC LIBRARY
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DETROIT

TECHNOLOGY DEPT.

★★★★★★ ★★★★★

LEWIS FOUNDRY & MACHINE
DIVISION OF BLAW-KNOX CO.
PITTSBURGH
ROLLS & ROLLING MILL MACHINERY

# the Crane SAFETY LIMIT STO

## -THAT SETS *New Standards of Performance*

C-H Type P-100 100 H.P.

THERE probably has never been a crane safety limit stop switch that so completely embodies *all* the wants of steel mill engineers as the new Type P-100 Cutler-Hammer Safety Limit Stop, for 41 to 100 H.P. installations or the new P-200 Safety Limit Stop for 101 to 200 H.P. installations. This is demonstrated by the fact that time after time engineers have taken one look at it and said: "That is what I want."

C-H Type P-200 200 H.P.

The photographs shown here tell their own story . . . of simple design . . . rugged construction . . . dependable, unfailing operation. Unquestionably, this new Crane Safety Limit Stop sets new standards in every way. CUTLER-HAMMER, Inc., 1269 St. Paul Ave., Milwaukee, Wis. *Associate:* Canadian Cutler-Hammer, Ltd., Toronto.

1892-1942 • 50th ANNIVERSARY

### CHECK THESE OUTSTANDING FEATURES

Low headroom required.

Totally enclosed tripping mechanism—can't be made inoperative by rain, snow, ice, dirt or falling objects.

Slate contact supports, slotted, provides ample insulation to ground.

Snap action make and break—hammer blow of tripping is absorbed by spring bumper.

Cover strong enough to support a man's weight.

Rigid one-piece construction of operating lever and tripping weight.

Only one hanging weight, and that has double guides, adjustable to meet any practical installation condition, to prevent fouling the weight by the hoisting cables.

The snap action is obtained from a compression spring, with a very low unit stress. Even if it should break, the mechanism will operate because spring is held in place by an inside guide.

Ball bearings, with means for lubricating by standard grease fittings, used throughout.

Flexible leads brought out for ease of installation.

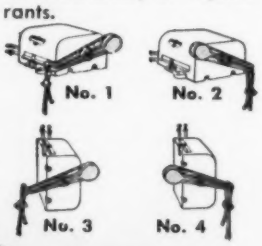
Gasketed cover to keep out dirt.

Mounting interchangeable with old style P-2.

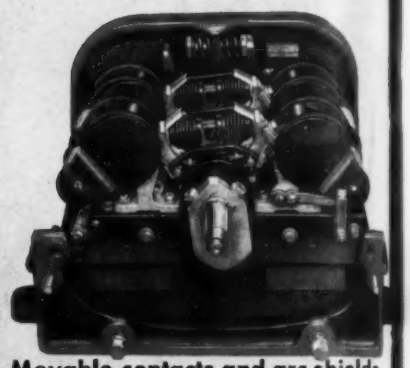
Blowouts latched in place when mounted in position (3) or (4).

Cover chained to case to prevent dropping to ground during inspection.

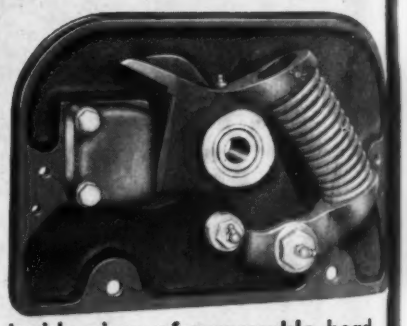
Operating lever can be mounted in any of 4 quadrants.




CUTLER-HAMMER
MOTOR CONTROL
C-H



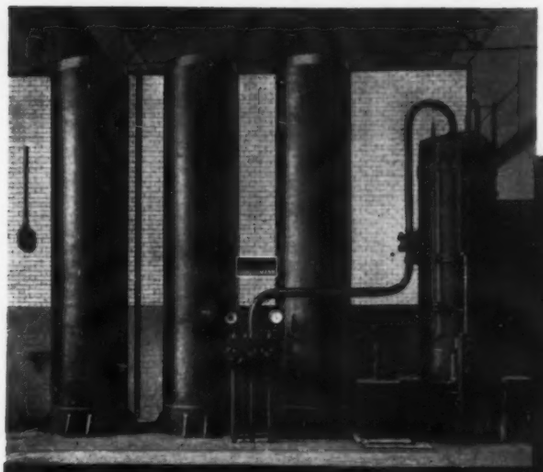
Movable contacts and arc shields in position. (Operating head removed).



Inside view of removable head, showing snap action mechanism.

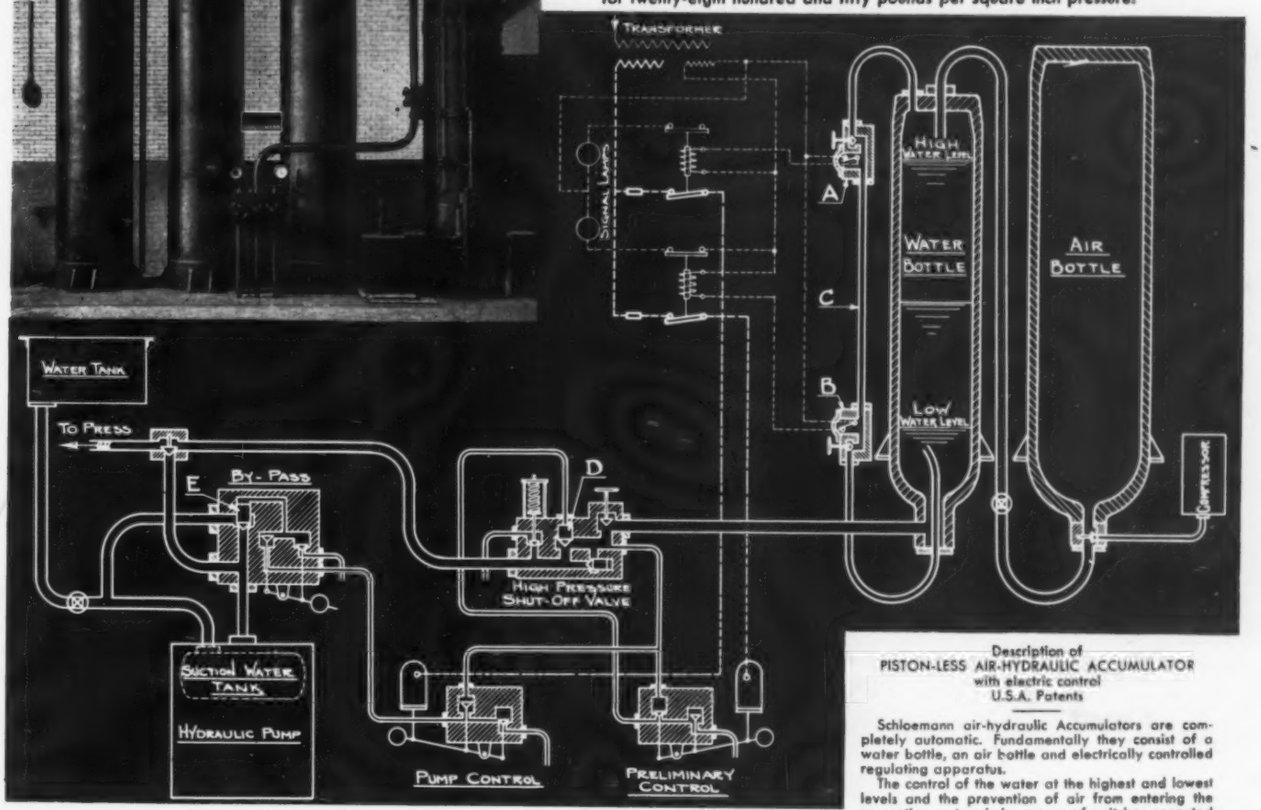
Combined operating lever and tripping weight.

Reset weight with adjustable hoisting cable guides.



Accumulators furnished in sizes from fifty gallons to twenty-five hundred gallons and for pressures up to forty-five hundred pounds per square inch.

System shown at left has two hundred gallons capacity and is designed for twenty-eight hundred and fifty pounds per square inch pressure.




Description of
PISTON-LESS AIR-HYDRAULIC ACCUMULATOR
with electric control
U.S.A. Patents

Schloemann air-hydraulic Accumulators are completely automatic. Fundamentally they consist of a water bottle, an air bottle and electrically controlled regulating apparatus.

The control of the water at the highest and lowest levels and the prevention of air from entering the connecting system is by means of switches operated by floats contained in chambers of a communicating tube "C." Thus the switch "A" in the upper chamber controls the operation of the hydraulic pump, while that in the lower chamber "B" controls the check valve "D" which shuts off the accumulator at lower water level.

The continuous running pump is controlled by closing the By-Pass check valve "E" by means of the pump control, causing it to idle by opening the same and returning the water to the suction end. Over-pressure is released through safety valves and is indicated by an alarm.

# SCHLOEMANN

## AIR-HYDRAULIC ACCUMULATORS

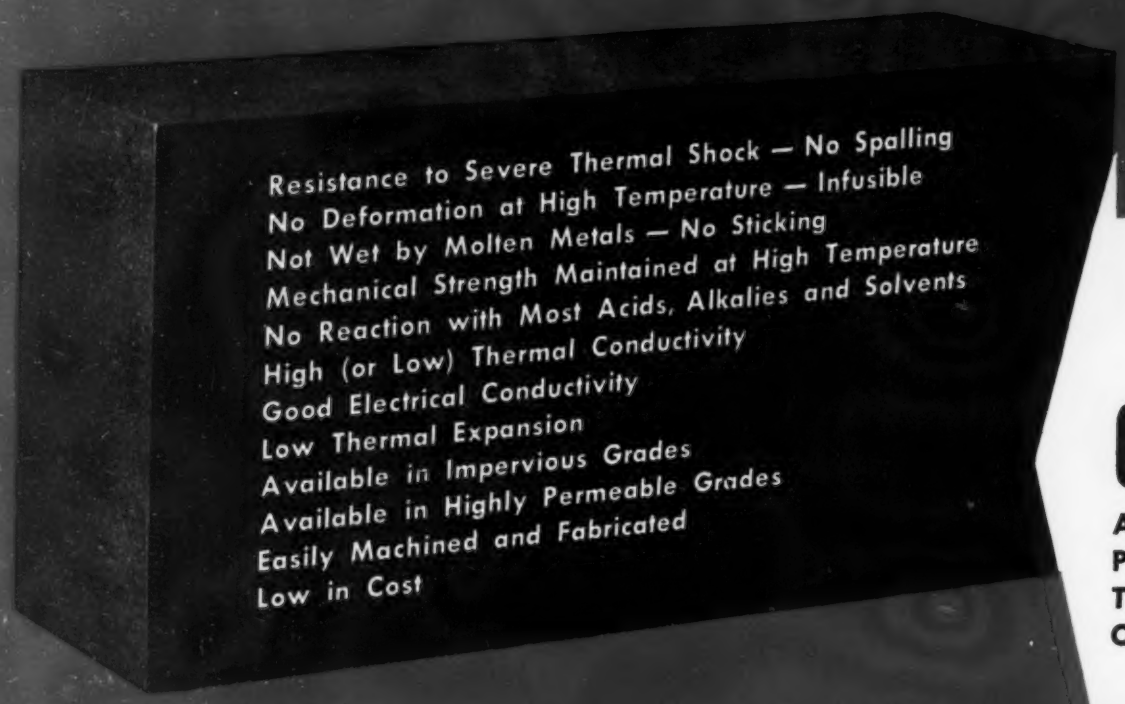
**HYDRAULIC EXTRUSION PRESSES**

**HIGH PRESSURE PUMPS**

**COMPLETE HYDRAULIC SYSTEMS**

ENGINEERING CORP. PITTSBURGH, PA.
Rolling Mill Machinery Hydraulic Presses

# YOU HAVE NEED FOR MATERIAL WITH THESE PROPERTIES


Resistance to Severe Thermal Shock — No Spalling
No Deformation at High Temperature — Infusible
Not Wet by Molten Metals — No Sticking
Mechanical Strength Maintained at High Temperature
No Reaction with Most Acids, Alkalies and Solvents
High (or Low) Thermal Conductivity
Good Electrical Conductivity
Low Thermal Expansion
Available in Impervious Grades
Available in Highly Permeable Grades
Easily Machined and Fabricated
Low in Cost

## CARBON AND GRAPHITE

**ARE THE ONLY MATERIALS POSSESSING THIS ADVANTAGEOUS COMBINATION OF PHYSICAL AND CHEMICAL PROPERTIES**

### ★ FABRICATED PRODUCTS

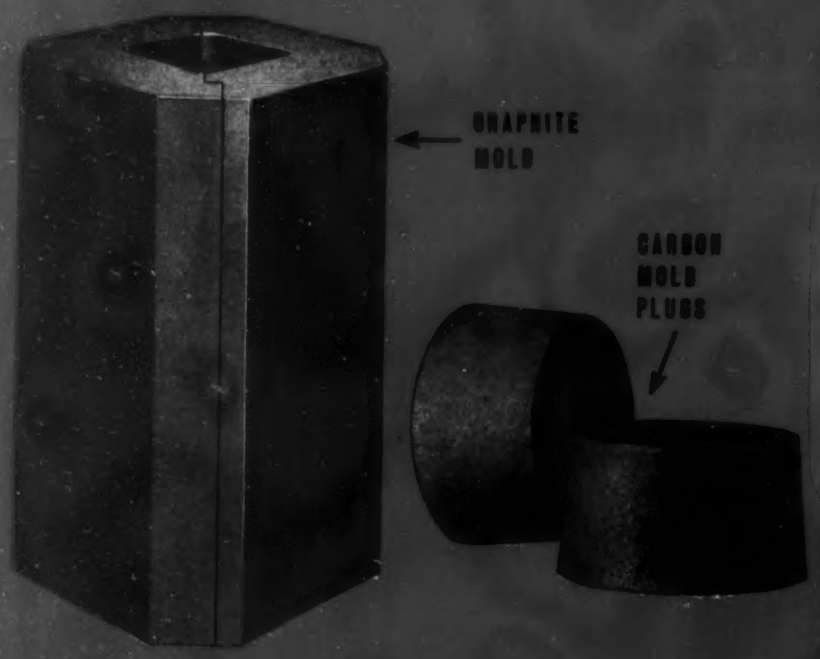
Practically any design can be machined or fabricated from stock materials.

### ★ STANDARD STOCK FORMS

BEAMS • BLOCKS • SLABS • PLATES • BRICK
RODS, ROUND AND RECTANGULAR • TUBES
CYLINDERS • PIPE • TOWER SECTIONS

### ★ MOLDED PRODUCTS

Carbon and graphite products are molded to form when quantity justifies.




IMPROVED PRODUCTION AND REDUCED MAINTENANCE
HAVE BEEN EFFECTED ON MANY METALLURGICAL APPLICATIONS BY USE OF

## NATIONAL and KARBATE
TRADE-MARK TRADE-MARK

## CARBON AND GRAPHITE PRODUCTS

SUCH AS

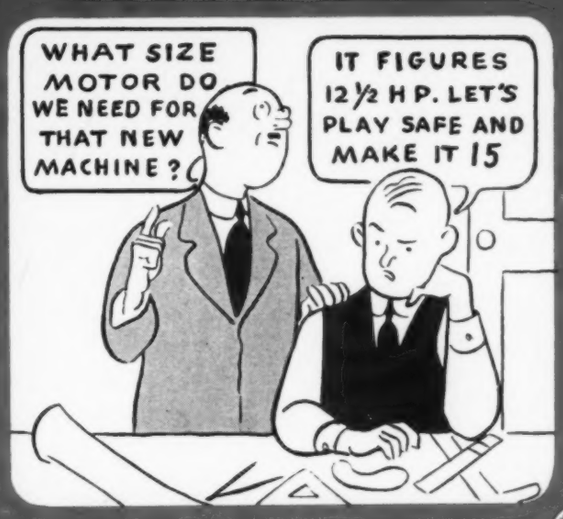
**Carbon mold plugs, inserts and stools. Carbon and graphite molds, crucibles and cores. Impervious carbon tanks and tank linings. Carbon trough and furnace linings. Carbon rolls and graphite electrodes for pickling tanks. "Karbate" impervious pipe, valves, pumps and fittings. Porous carbon and graphite diffusers and filters.**

**WRITE** for information on the use of carbon and graphite products for applications where a material with the properties listed above would be advantageous.

**NATIONAL CARBON COMPANY, INC.**
Unit of Union Carbide and Carbon Corporation
UCC
CARBON SALES DIVISION, CLEVELAND, OHIO
General Offices: 30 East 42nd St., New York, N. Y.
Branch Sales Offices: New York - Pittsburgh - Chicago - St. Louis - San Francisco

# Help s-t-r-e-t-c-h our Copper Supply by CONSERVATIVE GAMBLING

**It's too small for ALL the jobs to be done!**



YES, COPPER'S NO. 1 JOB now is in "shooting" material. To keep the shooting going we must conserve behind the lines. Our part is to build more motor per pound of copper, and we are finding ways to do it.

Your part, in which we are ready to help, is to take extra care in picking the right motor to make sure that it is not bigger than needed.

*Before ordering, check with these questions:*

- Could you draw from your stock of spare motors?
- Any motors that could be taken from machines removed from production lines because of switching from peacetime to war work?
- Could you get by with an open motor in place of an enclosed fan-cooled motor which may have been included in your plans?
- Would an intermittent-duty motor in a size smaller frame serve instead of a continuous-duty motor?
- Could you alter gears or pulleys to use next higher speed and thus drop a frame size?

All of these mean *triple* savings: (1) man-hours, (2) machine-hours *and* (3) materials . . . copper, steel, aluminum.

Reliance men skilled in Application Engineering are ready to help in checking duty-cycles, torque requirements, speeds. Let them aid in fitting the right motor to your machine. That's a definite part of our business.

**Two paragraphs from an ELECTRICAL WORLD Editorial headed "PLAYING SAFE"**

We must take chances. We have no room today for the philosophy of playing safe. We are not playing safe with our boys in the services, why should we do differently with objects of copper and iron and rubber?

* * * *

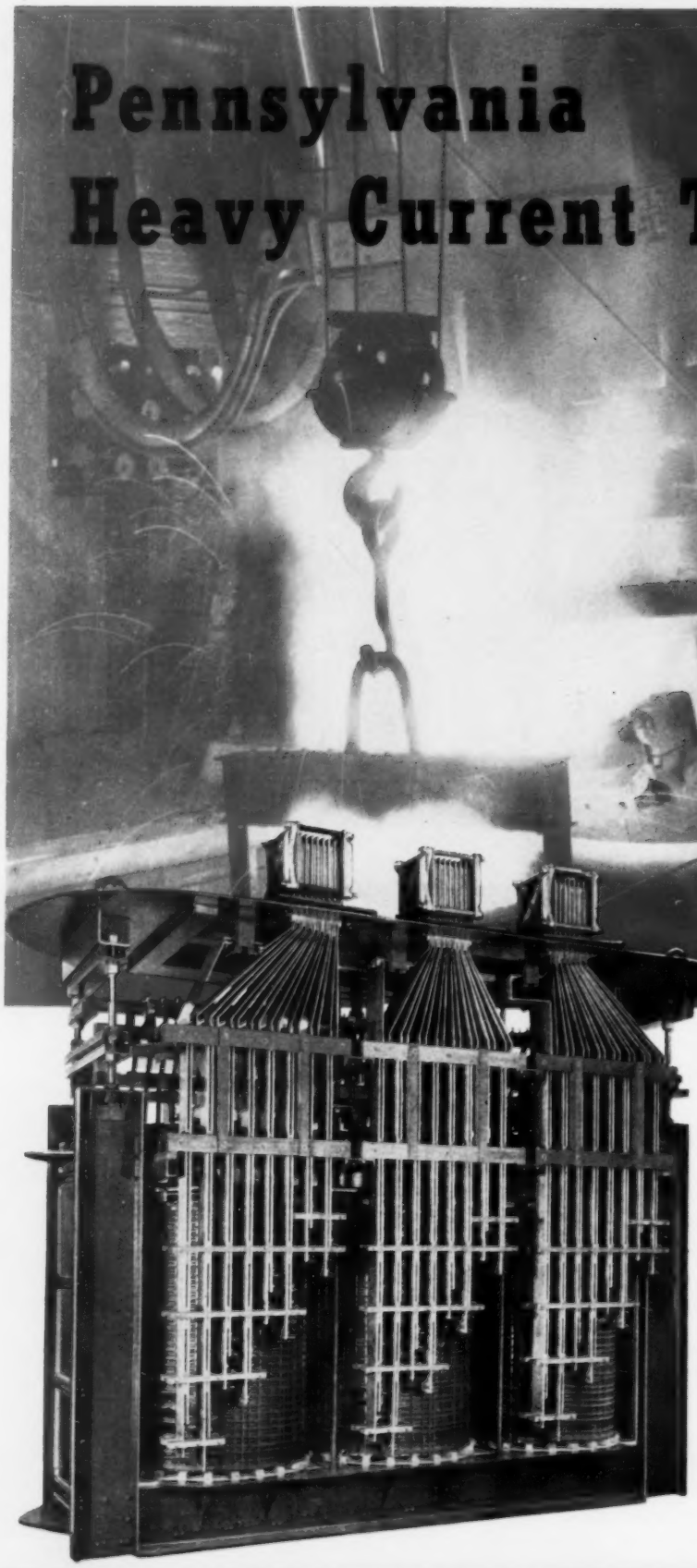
The expediency of war practice is not held up as good for peacetime, although there is every likelihood that, as the result of what we learn, some of it will be carried over. It must be recognized and promoted for what it is — materials saving by not playing safe.

**RELIANCE ELECTRIC & ENGINEERING COMPANY**
1088 IVANHOE ROAD • CLEVELAND, OHIO

BIRMINGHAM • BOSTON • BUFFALO • CHICAGO • CINCINNATI
DETROIT • GREENVILLE, S. C. • HOUSTON, TEXAS • LOS ANGELES
MINNEAPOLIS • NEW YORK • PHILADELPHIA • PITTSBURGH • PORTLAND, ORE.
ST. LOUIS • SAN FRANCISCO • SYRACUSE, N. Y. • and other principal cities

**RELIANCE A-C D-C MOTORS**

# Pennsylvania Heavy Current Transformers



*for*

**(1) Electric Furnaces**
Melting and refining of:
Iron, steel, ferro-alloys, copper alloys.
Production of graphite and carbide.

**(2) Rectifiers and Rotary Converters**
Electrolytic production and refining of:
Copper, aluminum, magnesium, tin, zinc, lead, iron, sodium, hydrogen, oxygen, chlorine.
Electroplating · Transportation Systems.

**(3) Electric Welding and Brazing Machines**
Automatic pipe welding.
Fabrication of metal products.

**(4) Electric Ovens**
Heat Treatment
Annealing
Drying of paint and enamel.

*Pennsylvania* TRANSFORMER COMPANY

808 RIDGE AVENUE, N. S., PITTSBURGH, PA.

SYMBOLS OF FREEDOM

A TYPICAL SWINDELL GAS FIRED CARBOTTOM FURNACE FOR PRECISION-CONTROLLED HEAT TREATING AND STRESS RELIEVING UNDER TODAY'S EXACTING PRODUCTION REQUIREMENTS

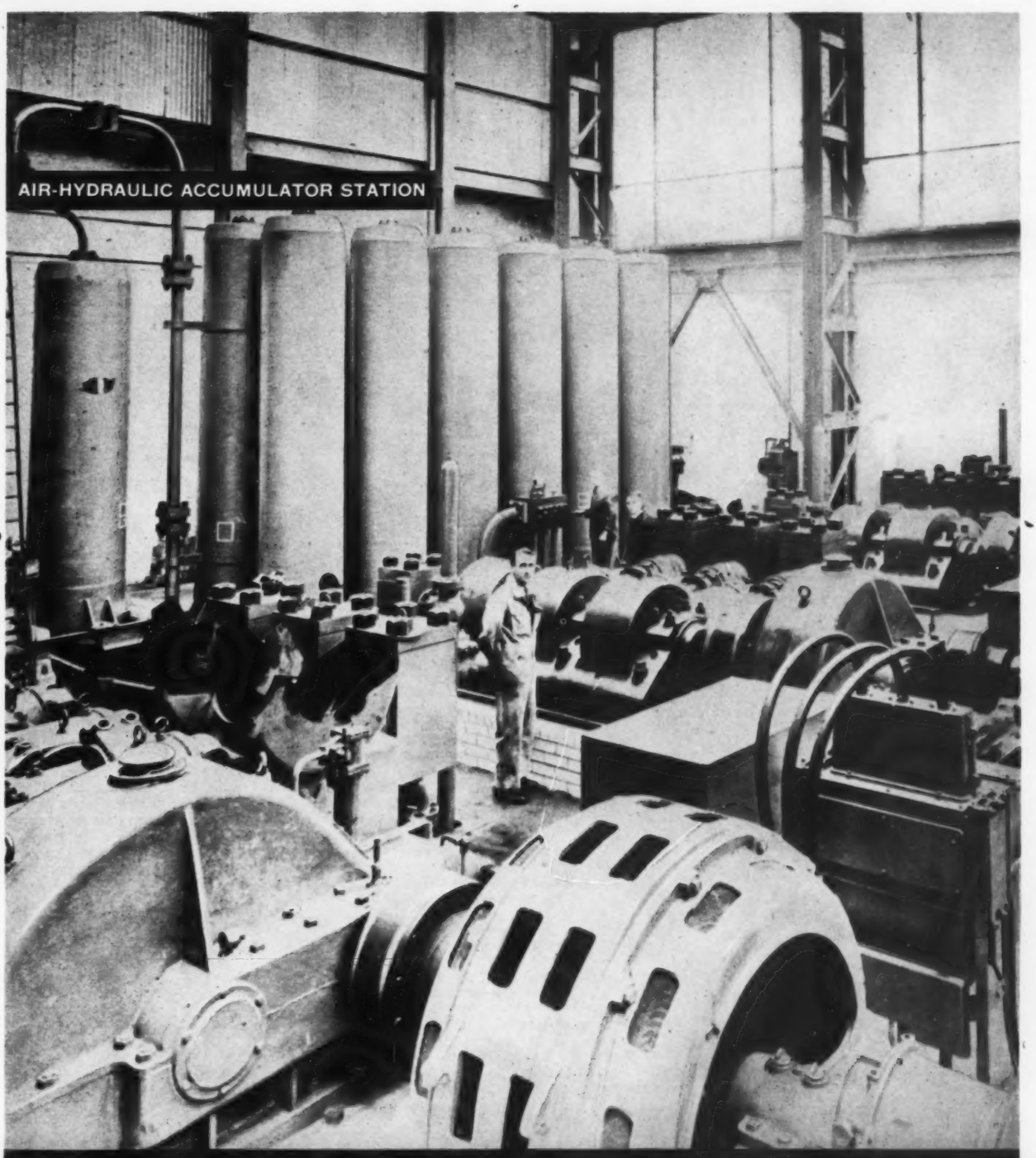
A RECENT INSTALLATION
9' x 48' x 12' ... AT THE
NATIONAL ANNEALING
BOX COMPANY
WASHINGTON, PENNA.

SWINDELL

SWINDELL-DRESSLER *Corporation*

DESIGNERS AND BUILDERS OF MODERN FURNACE EQUIPMENT SINCE 1850

PITTSBURGH, PA.

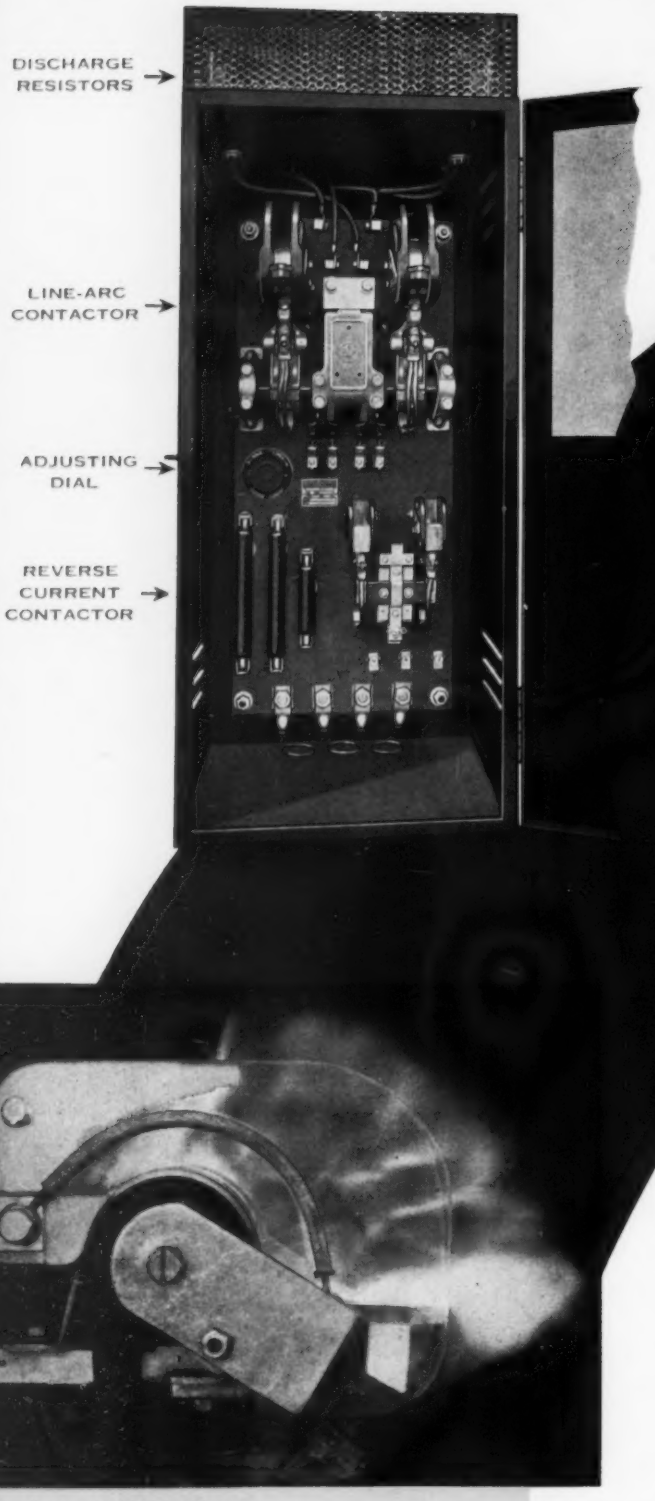



HYDROPRESS · INC.

ENGINEERS CONTRACTORS

HYDRAULIC PRESSES · ROLLING MILLS
PUMPS · ACCUMULATORS

570 LEXINGTON AVENUE · NEW YORK · N. Y.






This shows a LINE-ARC Contactor, specially fitted with glass arc shields, handling a 300% load. The glass was neither harmed nor smudged and is still in service at the EC&M Factory where visitors may witness this convincing demonstration of the LINE-ARC principle.

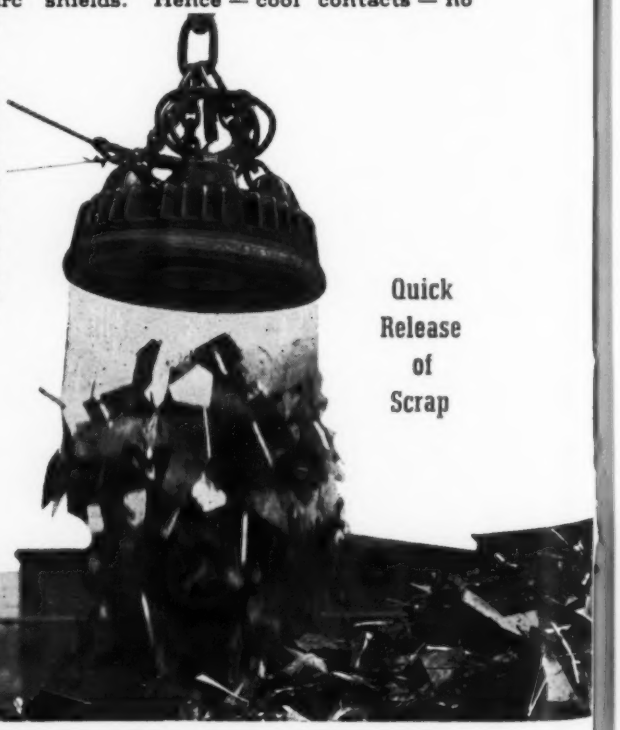
# *This Magnet Controller Has a* REPUTATION for Low Up-keep Cost

Opening the current to a magnet is a tough assignment. No ordinary contactor could long stand up under the vicious arc — caused by the big coil and mass of steel — every time the magnet is deenergized. But the EC&M *Automatic-Discharge* Magnet Controller is especially designed for this service with main contactor of special LINE-ARC design.

This controller operates with less wear . . . less expense for up-keep than any previous type. There is no destructive burning which wears away arc shields; contacts, of unusually high Brinnell hardness throughout their entire thickness, last longer because they operate cooler due to the LINE-ARC principle.

The LINE-ARC principle is simple . . . and automatic. There's nothing to adjust or wear out. At the instant the contacts start to separate, the arc is automatically transferred from the contacts to the arcing-plate and circular guard over the blow-out coil. Here, the arc can do no harm. It is stretched out in a line, centered *between* but *not touching* the arc shields. Hence — cool contacts — no burning of arc shields, and the name — LINE-ARC.

Many magnet users have replaced old controllers with the EC&M *Automatic*. They know that lower up-keep and faster operation (quick release of the load) will pay for this improved controller quickly. Write to-day for 2-color folder giving data on this controller for any make or size of magnet.



Quick Release of Scrap

Quick Release of Brake Shoes.

*An Exclusive EC&M Feature, assuring instantaneous release of ANY type of load—*one* setting for scrap—*one* setting for rails—*another* for baled scrap, etc. No compromise, but a fast release of every load.

THE ELECTRIC CONTROLLER & MFG. CO. E C & M CLEVELAND, OHIO

HEAVY DUTY MOTOR CONTROL FOR CRANES, MILL DRIVES AND MACHINERY • BRAKES • LIMIT STOPS • LIFTING MAGNETS AND AUTOMATIC WELD TIMERS.

## for Any Make or Size of Magnet—Use the EC&M Automatic Discharge Controller

## Who told Hitler we wouldn't fight?

Someone — whoever it was — blundered badly in the Greater Reich.

Hitler's international Auslander Organization — spies, to us — informed him that America would collapse before a shot was fired.

Internal dissensions would destroy us, and our industries would fall like ripe plums into the Nazi orbit.

Instead — 45,000 tanks, 60,000 planes, 20,000 anti-aircraft guns, 8,000,000 tons of shipping, *and more!*

### *Many U. S. Industries Beat War Production Schedules . . . YALE Pump Division Keeps a Year Ahead*

Like many a U. S. industry, we at Yale & Towne's Pump Division have long realized that output considered good enough last December 6, would not be good enough today.

As a result, America's war industries and our Armed Forces are now receiving Yale Rotary Piston Pumps in *1943* quantities. And yet, Yale quality has been preserved throughout.

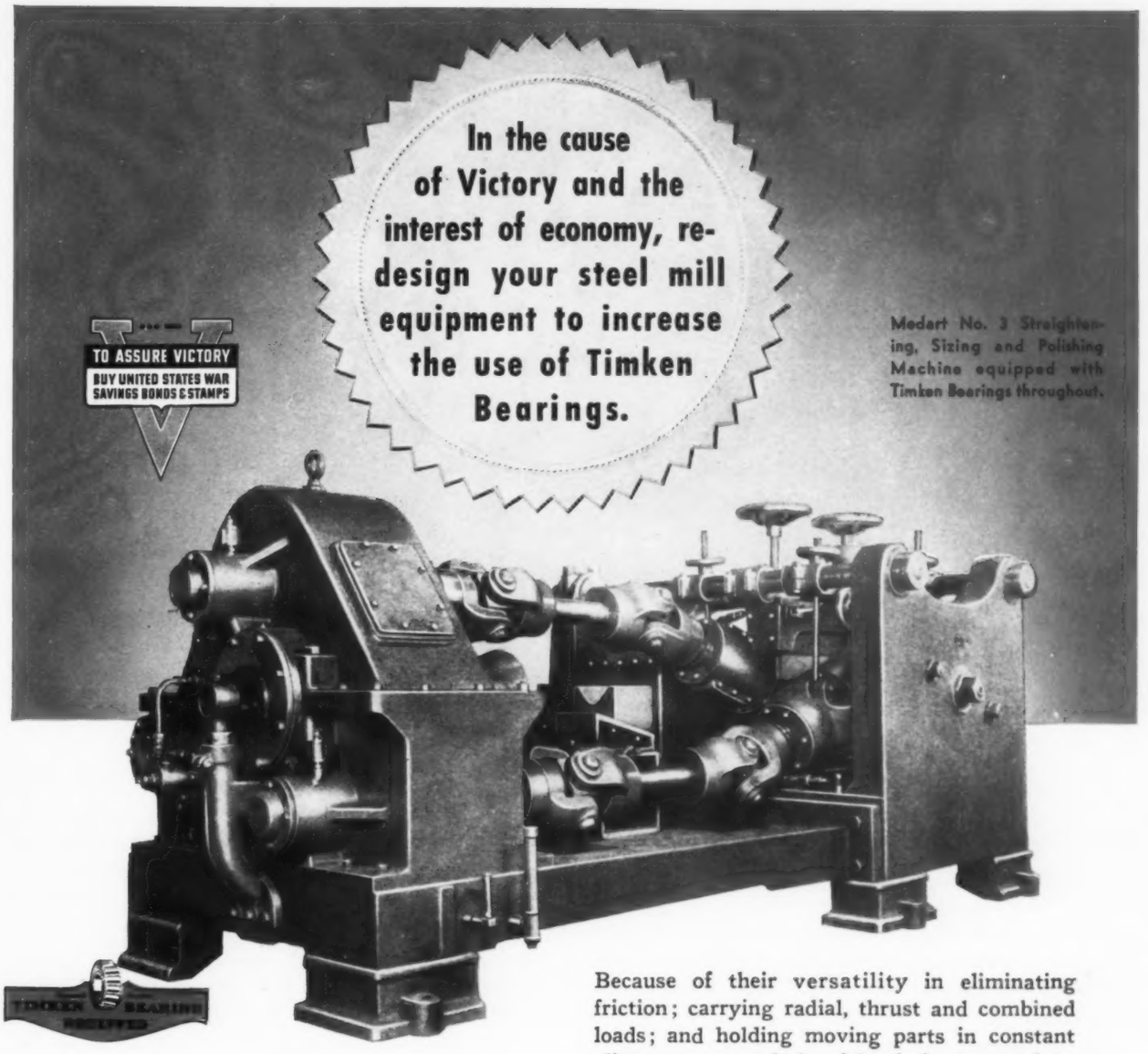
Yale pumps, which today cut fluid-handling costs, save fluid-handling time for victory, will be increasingly available to solve *your* fluid-transfer problems in the peacetime future.

TRADE YALE MARK
Pump Division

**THE YALE & TOWNE MANUFACTURING COMPANY**
**STAMFORD, CONNECTICUT, U. S. A., PUMP DIVISION**

Rolls are the only products made by Pittsburgh Rolls Corporation. Every working hour and every thought of all the employees of this company is directed toward improvement of the product—to make each roll shipped better than the one that preceded it.

# PITTSBURGH ROLLS


In the cause of Victory and the interest of economy, redesign your steel mill equipment to increase the use of Timken Bearings.
TO ASSURE VICTORY
BUY UNITED STATES WAR SAVINGS BONDS & STAMPS
Medart No. 3 Straightening, Sizing and Polishing Machine equipped with Timken Bearings throughout.
TIMKEN BEARING EQUIPPED

Thousands of Timken Bearing Equipped machines are working 24 hours a day, 7 days a week in American steel mills to help assure Victory.

They include a range of equipment that covers practically every operation connected with steel production—rolling mills, reels, drives, run-out tables, shears, straightening machines, levellers, overhead cranes, ingot cars, etc.

Because of their versatility in eliminating friction; carrying radial, thrust and combined loads; and holding moving parts in constant alignment; coupled with their tremendous strength and endurance, Timken Tapered Roller Bearings are able to meet every bearing requirement in steel mills with utmost efficiency and dependability.

Naturally, the more Timken Bearings there are in any machine the better it will operate, the longer it will last and the less it will cost for operation and maintenance. It will pay you to keep this in mind whether you are a machine designer, manufacturer or user.

**THE TIMKEN ROLLER BEARING COMPANY, CANTON, OHIO**

**TIMKEN**

TRADE-MARK REG. U. S. PAT. OFF.

***TAPERED ROLLER BEARINGS***

Manufacturers of Timken Tapered Roller Bearings for automobiles, motor trucks, railroad cars and locomotives and all kinds of industrial machinery; Timken Alloy Steels and Carbon and Alloy Seamless Tubing; and Timken Rock Bits.

# PLUGS and RECEPTACLES
## . . . Built for dependable service

★ Pyle-National plugs and receptacles are built for heavy duty service and proved by years of dependable performance in mills all across the country. Their substantial construction features include full bakelite insulation, protected contacts, and heavy steel or cast metal housings. These features mean uninterrupted service and safe, simple control of portable equipment circuits.

Pyle-National plugs and receptacles are available in a complete range of styles, sizes, and ratings for all types of applications, including styles particularly adapted to convenient handling of control and instrument circuits for operation of portable annealing furnaces and other heat treating equipment. The complete line includes styles for portable tools, signal and remote control circuits, extension lights, instruments, welders, shop tools, and many kinds of similar equipment.

Write for Pylet Catalog 1100 with complete listings of all types.

★ **General Purpose** plugs and receptacles: 1, 2, 3, 4, 5 poles; ratings 30, 60, 100, 200 amperes. Round prong contacts, rugged cast metal housings to withstand severe service.

★ **QuelArc** circuit breaking types: 2, 3, 4, 5 wire types, ratings up to 200 amperes. Exceptional protection to contacts for safe use as current rupturing devices.

★ **Triploc and Multiple Circuit** plugs and receptacles: 1, 2, 3, 4, 6 and 8 pole contact units, allowing assembly in combinations up to 32 poles. Manual and automatic release features. Ideal for portable tools, pyrometers, signal and control circuits.

★ **Midget Triploc,** compact, but with many exclusive heavy duty features for dependable service under severe conditions: 2, 3, 4 pole types.

★ **Battery Charging** equipment, designed for safe, convenient handling of industrial truck and tractor battery service.

PYLE-NATIONAL
ELECTRICAL EQUIPMENT
• SINCE 1897 •

**THE PYLE-NATIONAL COMPANY**
**1334-58 N. Kostner Ave. • Chicago, Ill.**
*Offices:* New York, Baltimore, Pittsburgh, St. Louis, St. Paul, San Francisco

CONDUIT FITTINGS • FLOODLIGHT PROJECTORS • LOCOMOTIVE ELECTRICAL EQUIPMENT

WAGNER POWER TRANSFORMER

# YOU CAN COUNT ON WAGNER

## ... for Dependable Transformer Performance

BUY U.S. WAR BONDS

In the steel industry, where production must be maintained at an all-time high to supply the enormous quantity of steel necessary to produce war equipment, dependable electric power is of major importance.

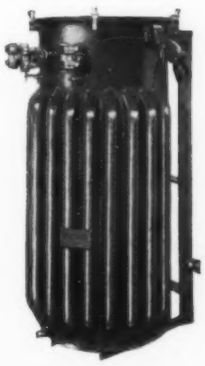
The transformers are the vital links in any electric power distribution system. If the transformers fail, unsatisfactory service results – production is delayed and operating costs go up.

Wagner Transformers have established outstanding records in the steel industry for continuous service and long life. Carefully controlled production methods, highest quality materials, rigid inspection and tests, plus 50 years of transformer engineering experience, are just a few of the reasons why you can count on Wagner for dependable transformer performance.

Wagner can take care of all of your transformer requirements. 25 branch offices, located in as many principal cities and manned by trained field engineers, are always ready to help you.

WAGNER NOFLAMOL TRANSFORMER

WAGNER AIR-COOLED TRANSFORMER



WAGNER HEX TRANSFORMER

T42-11

### *Wagner Transformer Features:*

Liberal insulation—extra end turn insulation provides added protection against line surges and voltage disturbances . . . Heavy tank construction—heavy steel plate, electrically welded, sand-blasted and flow-painted . . . Core iron of non-aging silicon steel—has high magnetic permeability and has very low hysteresis and eddy-current losses . . . Tap changer contacts of low resistance and with high over-current capacity, securely held in place and accurately aligned . . . Bushings—wet-processed porcelain, either solid or oil-filled, with ample mechanical and electrical strength to withstand stresses encountered in service . . . Transformer Oil—has high dielectric strength, proper viscosity, safe flash-point, and resistance to sludging.

*Complete Information sent on Request*

## Wagner Electric Corporation

6400 Plymouth Avenue, Saint Louis, Mo., U.S.A.

TRANSFORMERS • MOTORS • FANS • BRAKES

# The WEAN ENGINEERING COMPANY, Inc. • WARREN, OHIO

SPECIALISTS IN SHEET, TIN AND STRIP MILL EQUIPMENT

ARMOR PLATE LEVELLERS

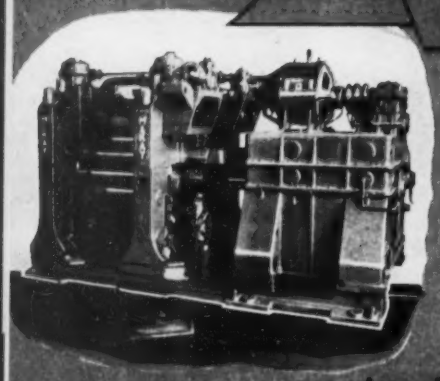
HI-SPEED SHEET AND TIN MILL SHEAR LINES

ELECTROLYTIC & BONDERIZING TIN PLATE EQUIPMENT

WILSON TUBE ANNEALING FURNACES

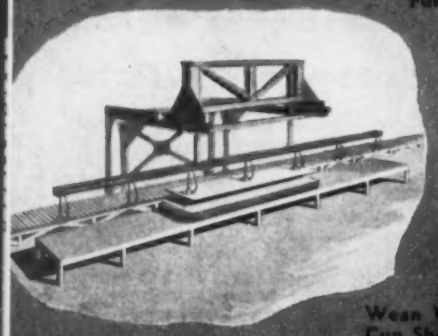
WEAN VACUUM CUP SHEET AND PLATE LIFTERS

CONTINUOUS STRIP PICKLING, SLITTING, SIDE TRIMMING, AND RECOILING LINES

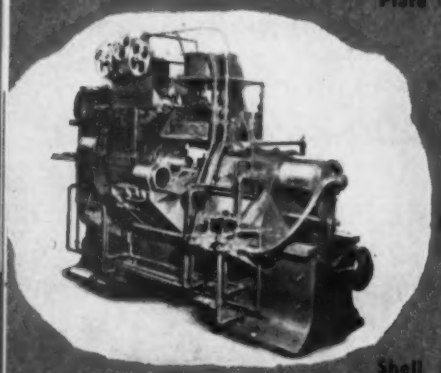


Armor Plate Leveller

Wilson Tube Type Annealing Furnace



Wean Vacuum Cup Sheet and Plate Lifter



Shell and

*Subsidiary Company*

THE BRODEN CONSTRUCTION CO.
CLEVELAND, OHIO

*Associated Companies*

LEE WILSON ENGINEERING CO.
CLEVELAND, OHIO

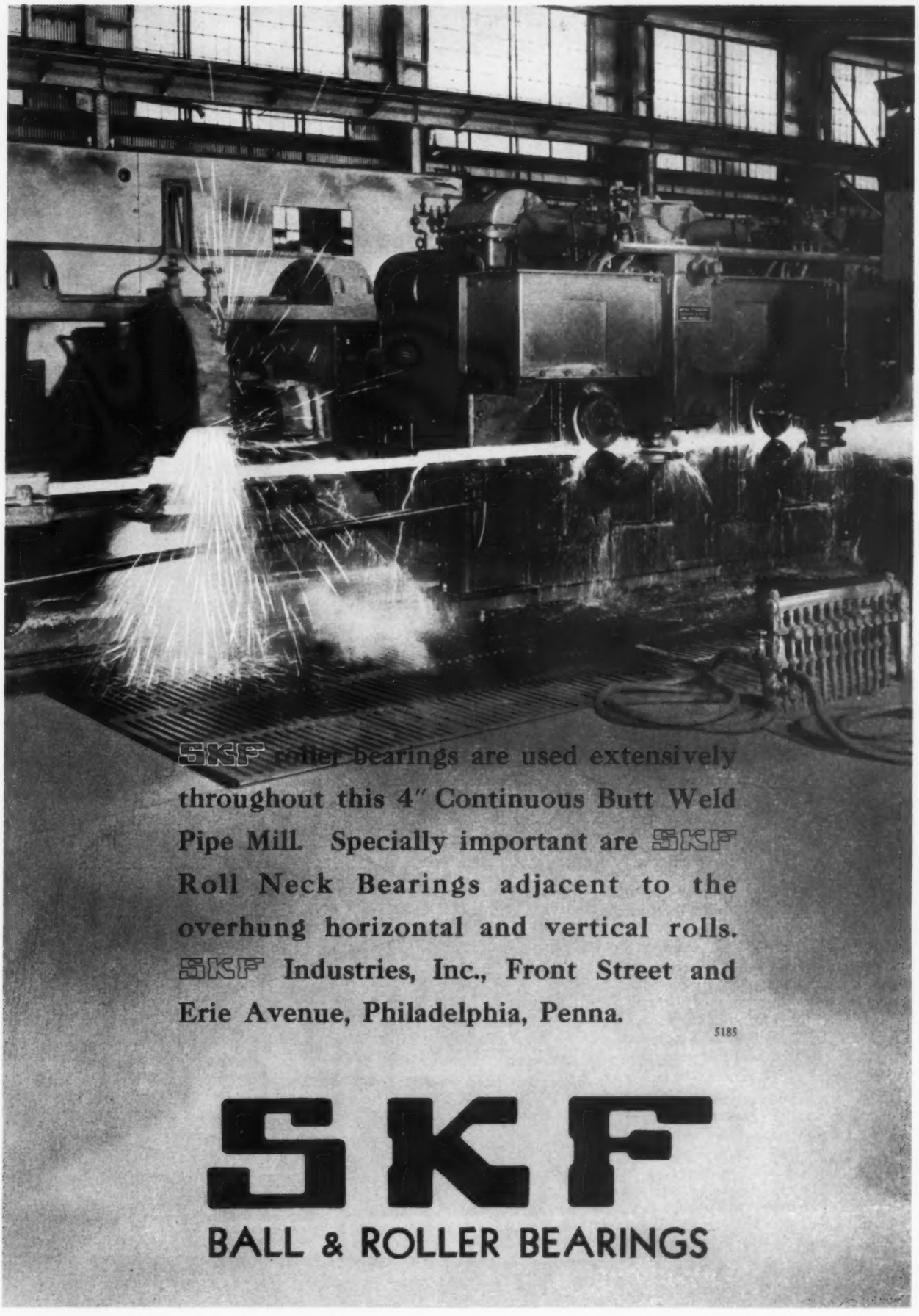
THE McKAY MACHINE CO.
YOUNGSTOWN, OHIO

FLINN & DREFFEIN CO.
CHICAGO, ILL.

THE WELLMAN SMITH OWEN ENGR. CORP., LTD.
LONDON, ENGLAND

THE HALLDEN MACHINE CO.
THOMASTON, CONN.

THE WEAN ENGINEERING CO. OF CANADA, LTD.
HAMILTON, ONT.


SKF roller bearings are used extensively throughout this 4" Continuous Butt Weld Pipe Mill. Specially important are SKF Roll Neck Bearings adjacent to the overhung horizontal and vertical rolls. SKF Industries, Inc., Front Street and Erie Avenue, Philadelphia, Penna.
5185
SKF
BALL & ROLLER BEARINGS

Micromax, hung in improvised mounting, works while it waits for its steel panel to arrive. With it to help him, the furnace operator gets much closer control of a frit smelting furnace in plant of U. S. Stamping Co.

# ENAMEL WARE MFR. STEPS UP PRODUCTION

## By Using Micromax Control for Frit Furnaces

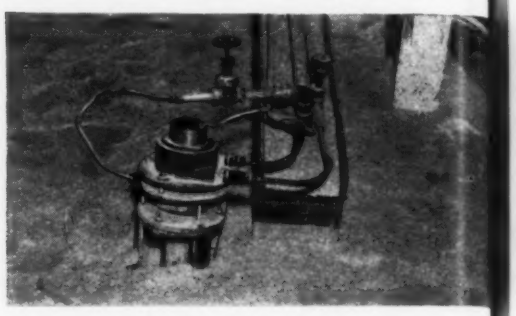
Faced with the need for a big increase in the frit-smelting capacity of its gas-fired pot furnaces, the U. S. Stamping Co. has found Micromax Pyrometers "very helpful" in securing the close, dependable temperature-control which is necessary to such an increase.

The instruments for one furnace consist of a Micromax Round Chart Recorder, range 1100-2300 F, and a 24-inch open-end Rayotube radiation-detector. The Rayotube is mounted in an iron tripod on the furnace roof. Its open-end tube extends through a hole in the roof (to which it is of course luted with fire-clay) and is aimed at the surface of the charge in one of the pots. The Micromax Pyrometer to which the Rayotube is connected records this radiation as temperature, so that when the workmen regulate the fuel valves, they are being guided by the radiation from the surface of the bath, instead of depending, as they formerly did on the temperature of the furnace. The result is a uniformity of temperature never achieved before in these furnaces.

If the benefits of automatic temperature control of the furnace are desired in such an application, the best practice is to use a closed-end Rayotube (instead of the open-end one) in the furnace roof, and to equip the valve and the Micromax Pyrometer for full-floating, proportional Micromax Electric Control. Under this system, the Micromax brings the furnace up to temperature on the basis of the closed-end Rayotube, and thus lets the furnace itself select the fastest heating rate which it can stand, and then, when at temperature, call for such heat as it needs to maintain its temperature.

Under this control, a change in temperature will start the exactly-correct control action even while the variation itself is still being recorded. Furthermore, the control operates on changes too small to be clearly visible on the extremely legible record. Thus, the effects of fluctuations in weather, fuel pressure, radiation, etc., are headed off as they develop, and the full benefits of automatic control are attained.

If, for any reason, the control outlined above is not desired, various other systems can be used: (1) The earliest,



Rayotube looks through the roof of frit-smelting pot furnace. Gets actual temperature of the frit.

and probably still the most familiar, puts a thermocouple, instead of a Rayotube, in the furnace roof, and uses an on-off fuel-valve drive. (2) Another system uses the thermocouple and M.E.C. proportional-acting valve drive. (3) A third system uses the closed-end Rayotube, with on-off drive. Other systems permit the combined use of two valve-drive methods, or of two Micromax Pyrometers, or of both.

The correct system, for any war-busy furnace, will be gladly selected for you if you will forward details of your problem.

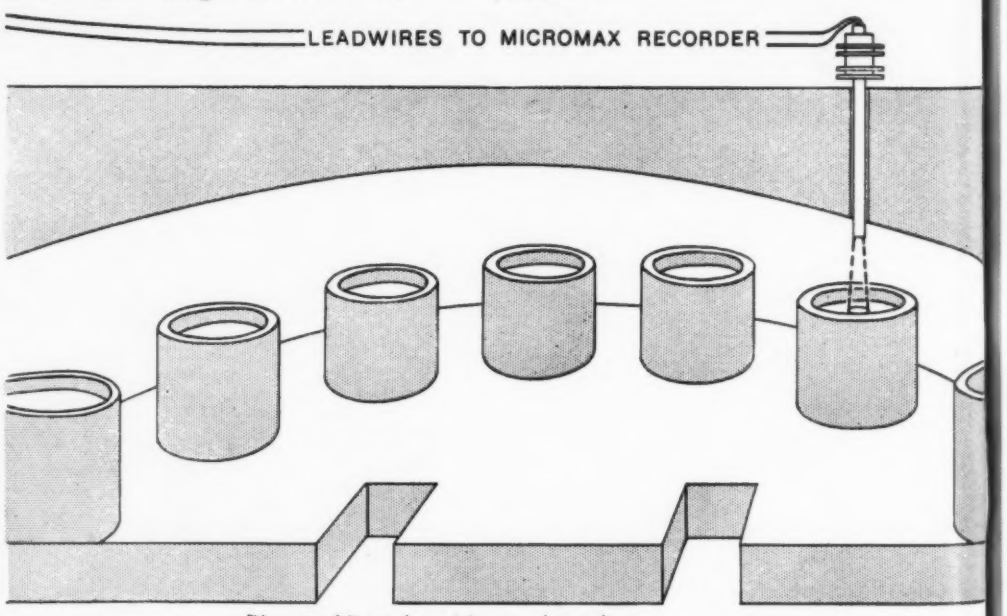



Diagram of Rayotube and furnace shown above.

Jrl Ad N-33-644(2)

LEEDS & NORTHRUP COMPANY, 4942 STENTON AVE., PHILA., PA.

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MEASURING INSTRUMENTS · TELEMETERS · AUTOMATIC CONTROLS · HEAT-TREATING FURNACES

# The Second Vital Move

on the chessboard of global war is beginning—*the offensive!* But this could not have taken place until the first move—the production of the implements of war—was well begun. Management and labor, working together, are delivering tools of war in ever increasing quantities. » » A flood of planes, ships, tanks and other mobile units is pouring from American factories. Okonite is making many of the insulated wires and cables on which they depend for power, control and communication. Even the dearth of rubber has not stopped us, because our research laboratories years ago learned how to use synthetics and other materials for insulation. » » Without the constant faith in our country's future that spurred us and hundreds of other American Industries to maintain these research laboratories—our armed forces might still be waiting for the necessary tools of Victory.



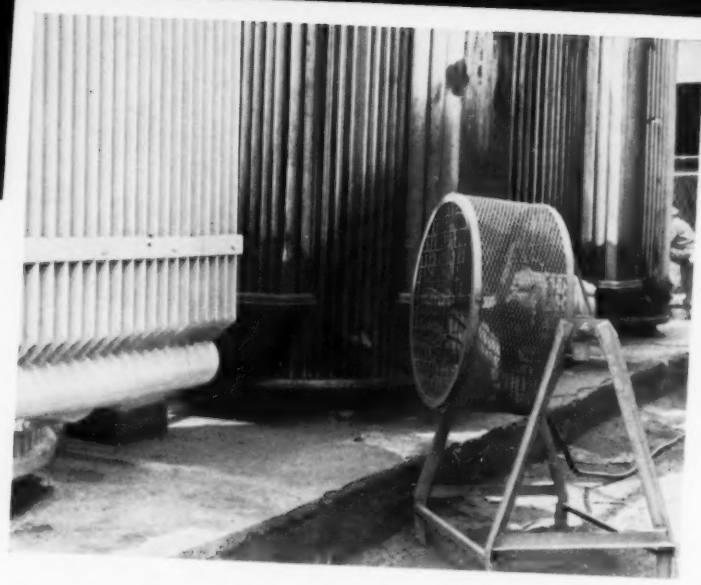

**THE OKONITE COMPANY**
**Executive Offices: Passaic, N. J.**
**Branch Offices in Principal Cities**

BUY U. S. WAR BONDS *Every Payday All Okonite Employees* BUY U. S. WAR BONDS

# Let *Truflo Fans* . . .

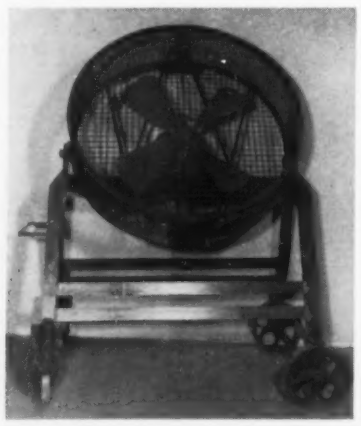
## Help keep your workmen on their toes

Portable Fan No. TF-100, recognized as standard in many of the country's largest mills. Sizes from 12 in. to 36 in. in diameter.



Portable Fan No. TF-300 in operation, cooling large transformers in strip mill.

Crane Cab Fan, for cooling crane cab interiors and other confined areas. Available in 12 in. and 18 in. sizes, adjustable both horizontally and vertically.



Portable Fan No. TF-300W. Angle iron support adjusts for vertical or horizontal discharge through almost 360°.

It's more important now than ever before to keep your workmen comfortable. For comfortable workmen are more efficient, produce more work in a given time.

Truflo Fans can help you keep your workmen on their toes. All Truflo Fans are designed and built correctly for efficient, economical operation — they move more air per dollar. Write for free literature on any of the following styles:

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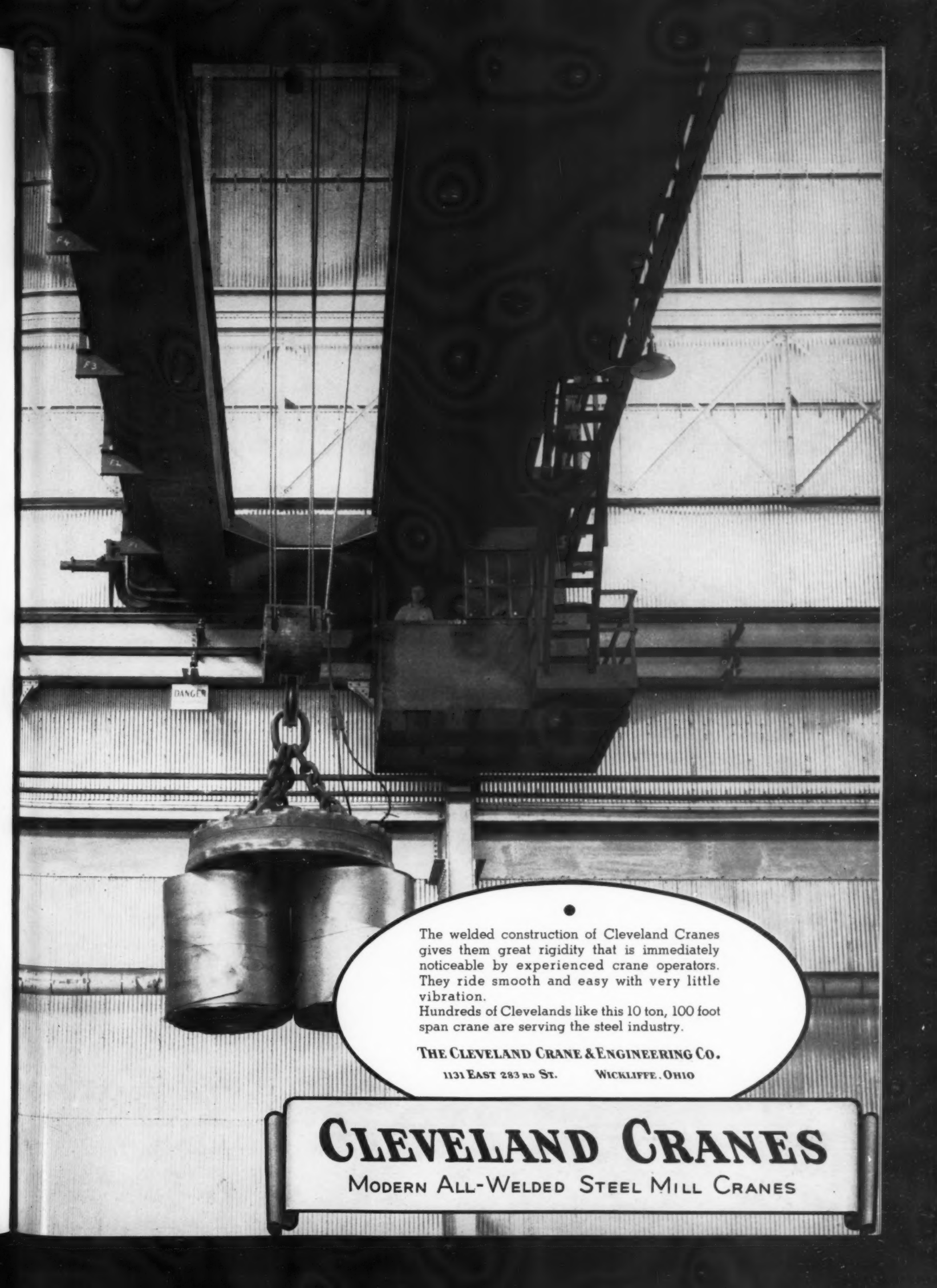


The welded construction of Cleveland Cranes gives them great rigidity that is immediately noticeable by experienced crane operators. They ride smooth and easy with very little vibration.
Hundreds of Clevelands like this 10 ton, 100 foot span crane are serving the steel industry.

THE CLEVELAND CRANE & ENGINEERING CO.

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MODERN ALL-WELDED STEEL MILL CRANES

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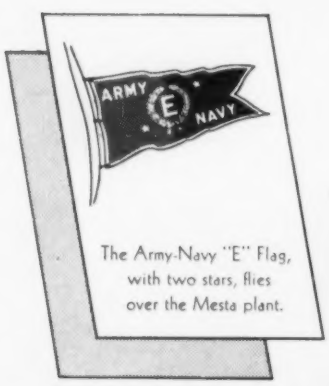
**BACKING-UP ROLLS**

**FOR FOUR HIGH HOT AND COLD STRIP MILLS**




The Army-Navy "E" Flag, with two stars, flies over the Mesta plant.

**MESTA MACHINE COMPANY · PITTSBURGH, PA.**

# FREYN DESIGN

## BLAST FURNACE EQUIPMENT

*Plays a Leading Role*

IN THE CURRENT EXPANSION PROGRAM

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| 45 - Distributor Controls | 97 - Stockline Recorders |
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| 11 - Stock Watering Devices | 24 - Gas Cleaning Equipments |
| 18 - Stove Linings | 13 - Equalizing Valves |
| 72 - Hot Blast Valves | 6 - Sludge Systems |
| 153 - Chimney Valves | 23 - Blowoff Valves |
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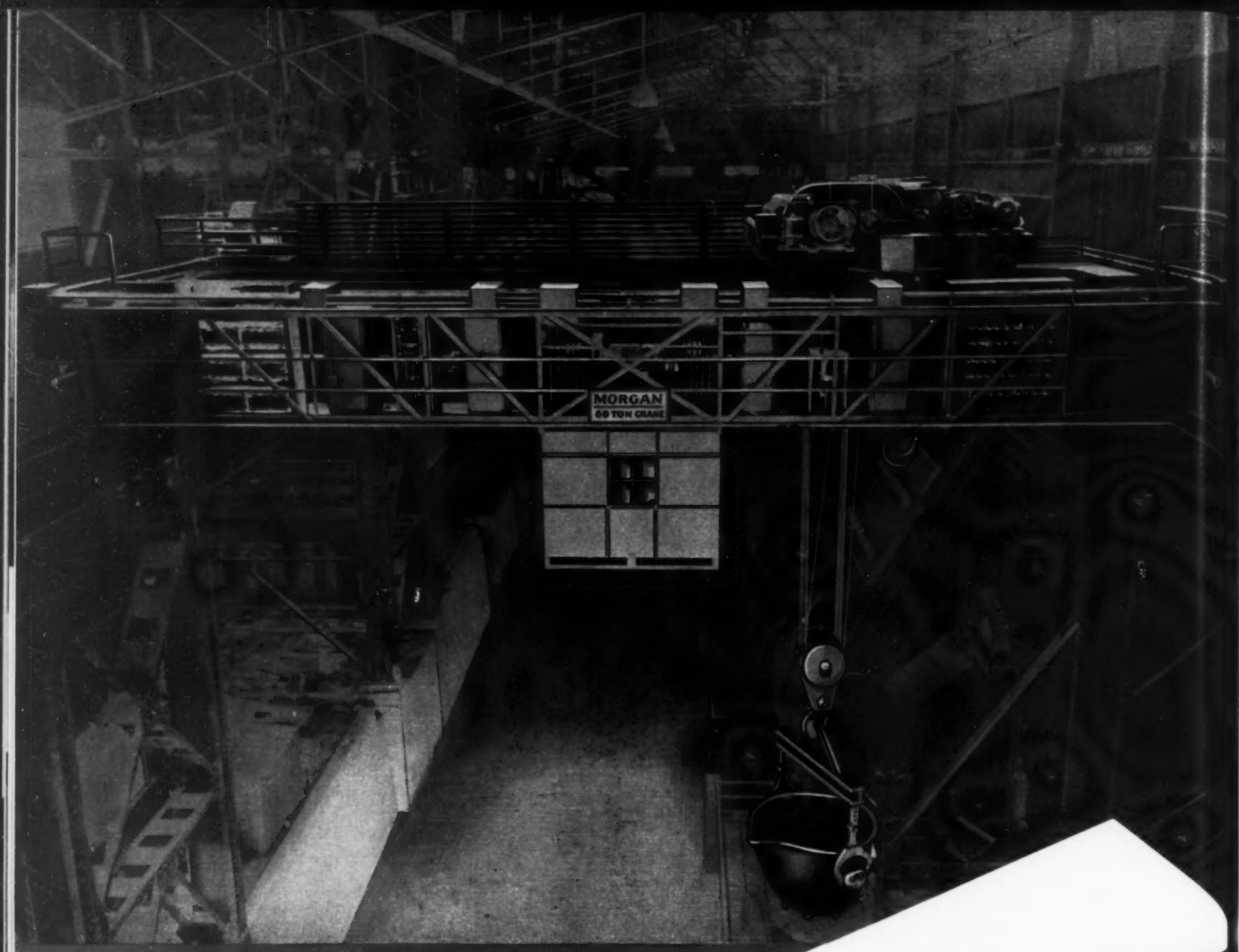


**MORGAN 60-TON 60'-0"
SPAN CONVERTER AISLE CRANE**

BUILT BY **MORGAN** *Engineering*

● Illustrated is a Morgan heavy duty mill type crane in a converter aisle. It is equipped with fabricated welded trolley and bridge trucks; hydraulic bridge brake and anti-friction bearings. Trolley is of the gear box type having two 60-ton identical hoists using plain motors with flexible couplings. An auxiliary girder is provided for supporting the center cage. As a safety feature, special relays are incorporated in the control circuit to limit the torque of the hoist motors when "pulling collars." On such crane equipment for copper smelter service, the stability of Morgan Engineering has long been well established.

**THE MORGAN ENGINEERING CO.**
**ALLIANCE, OHIO.** 1420 Oliver Building, Pittsburgh

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# SPEED UP BILLET CHIPPING AS MUCH AS 90%

## CLEAR FOR ACTION!

Speed has always been important to economical production — but today it is even more important to the all-out Victory drive. Have you checked on the possibilities of speeding up billet-chipping? Do you know that the

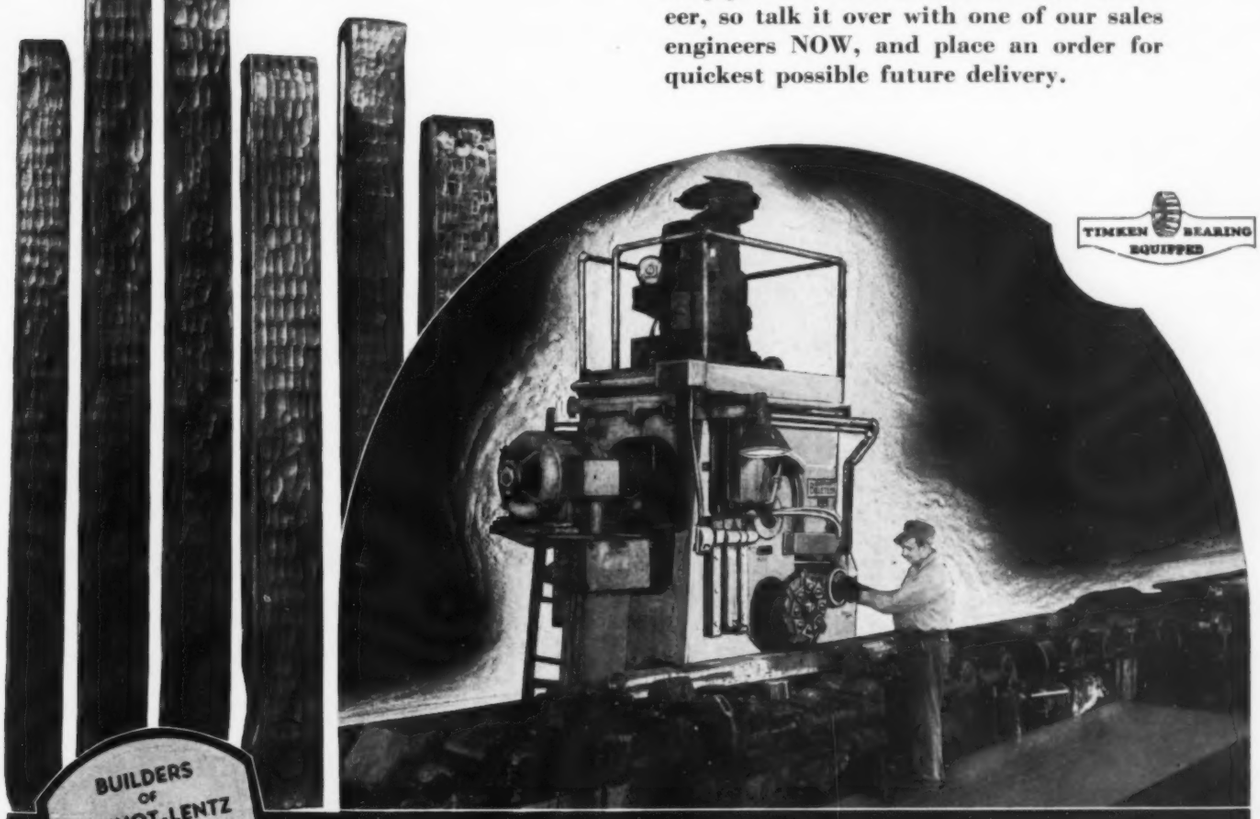
**BILLETEER**

and *one* operator will clean as many billets as a crew of 10 to 20 skilled workmen with air chipping tools? Furthermore, the Billeteer easily and economically salvages billets that heretofore were unprofitable to clean by hand.

These are cost-cutting features, too, that mean supremacy in peace as well as in war.

Very high priority rating has been given this equipment. We have been unable to keep pace with the demand for the Billeteer, so talk it over with one of our sales engineers NOW, and place an order for quickest possible future delivery.

Send for our descriptive Brochure. It gives information vital to every steel plant engineer and production executive.




BUILDERS OF BONNOT-LENTZ BILLETEERS ALSO CRUSHING PULVERIZING AND MIXING EQUIPMENT

THE Bonnot COMPANY
STEEL EQUIPMENT DIVISION
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# HERE'S THE NEWEST T
# FURNACE CONTROL..

## NEW "Regulex" EXCITER

☛ Produces electrode speeds proportional to deviation of controlled quantity from desired value, compensates rapidly for sudden current fluctuations—yet control is stable.

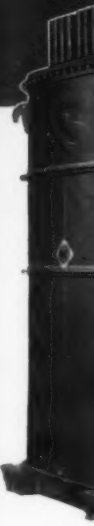
☛ No large resistance in circuit—maximum rated speed of electrode motors is available for automatic correction after a "cave-in". Electrode burning is minimized.

☛ Heavy starting surges, caused by throwing the 250 volt d-c motor across-the-line are done away with by variable voltage control. Also, torque is applied gradually to the electrode rope system, reducing effect of rope stretch to minimum.

☛ Arc furnace power and control are independent of d-c shop supply interruptions when desired — fewer furnace shutdowns means increased production.

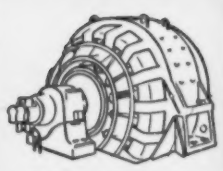
☛ Regenerative braking action of the "Regulex" exciter unit stops electrode motors fast.

☛ Uses no contacts or motor line contactors. Maintenance is slashed.

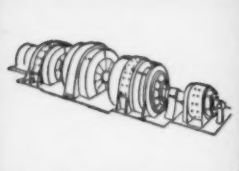


This 3,000 transformer plete line nace auxili built by A

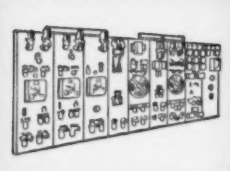
*Get "All Out" production with* **ALLIS-CHALMERS**



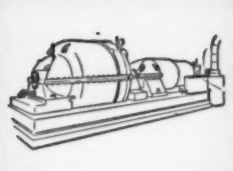
Main Drive Motors



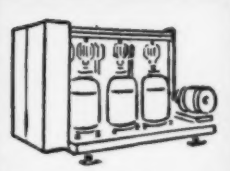
Motor Generator Sets



Switchboards & Control



Blast Furnace Blowers



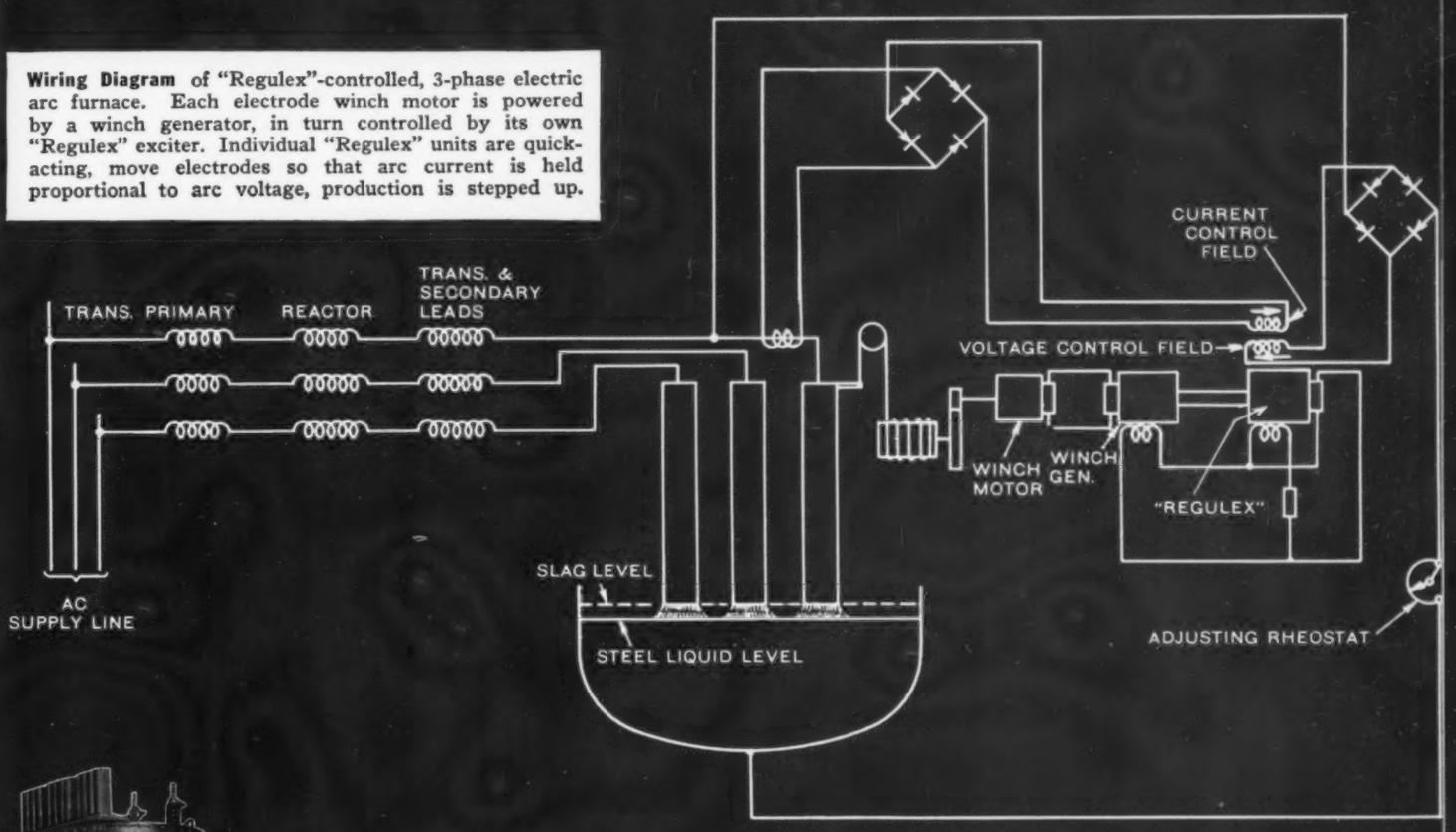
Mercury Arc Rectifiers

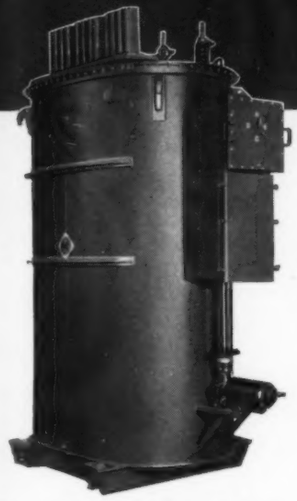
C

D

# THING IN ELECTRIC

**Wiring Diagram** of "Regulex"-controlled, 3-phase electric arc furnace. Each electrode winch motor is powered by a winch generator, in turn controlled by its own "Regulex" exciter. Individual "Regulex" units are quick-acting, move electrodes so that arc current is held proportional to arc voltage, production is stepped up.



This 3,000 kva indoor furnace transformer is part of the complete line of electric arc furnace auxiliaries designed and built by Allis-Chalmers.

## NOW YOU CAN INCREASE PRODUCTION, CUT COSTS!

THE newest thing in electric arc furnace control—Allis-Chalmers revolutionary "Regulex" exciter—is bringing increased production wherever it's installed—thanks to its engineering advances that give you improved operation.

In one plant this smooth, fast-acting amplifying generator actually permitted *one extra "heat" per day!* This output was achieved on a furnace side-by-side with two identical units equipped with conventional control.

So pleased were the operators of one "Regulex" exciter-controlled furnace after only a short period of operation that they ordered eight more complete units for their other plants.

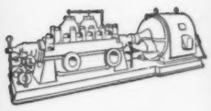
Remember, Allis-Chalmers makes a complete line of furnace electrical equipment—transformers, motors, generators, circuit breakers and control panels. Undivided responsibility pays a dividend because there's no "buck-passing."

If you've had trouble keeping your furnace power supply stable, or if you've been replacing electrodes too often, you'll find it profitable to find out about the new Allis-Chalmers control built around the "Regulex" exciter.

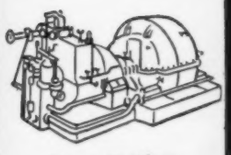
For complete information, call the district office near you . . . today. Or write direct to ALLIS-CHALMERS MANUFACTURING COMPANY, MILWAUKEE, WISCONSIN.

A-1573

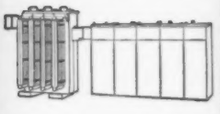
# COOPERATIVE ENGINEERING



Descaling Pumps

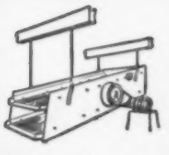


Steam Turbines



Unit Substations

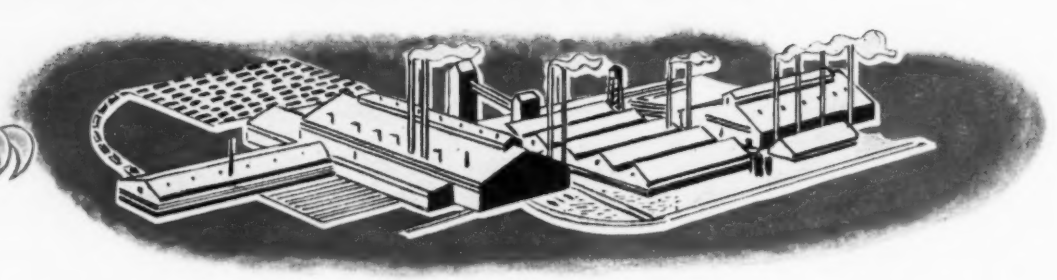
Gyratory & Jaw Crushers



Vibrating Screens

# Speeding Victory

## AT IT'S SOURCE



● **TIME WAS NEVER MORE PRECIOUS** than in this national emergency. Every step that can be saved . . . every unnecessary motion that can be eliminated . . . every ounce of energy that can be conserved helps to speed the tools of victory and shorten the war.

Keeping munitions, materials, and machinery supplies moving faster and with less worker fatigue is the function of Mathews Conveyer Systems.

Mathews engineers have helped hundreds of manufacturers of war material speed up production schedules with no increase in man-and-machine hours! They are ready to work with you in your effort to increase your production.

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# IRON AND STEEL ENGINEER

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VOL. XIX NO. XII

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# MERCURY-ARC RECTIFIER VS. MOTOR GENERATOR

*By L. R. Milburn*

ELECTRICAL ENGINEER

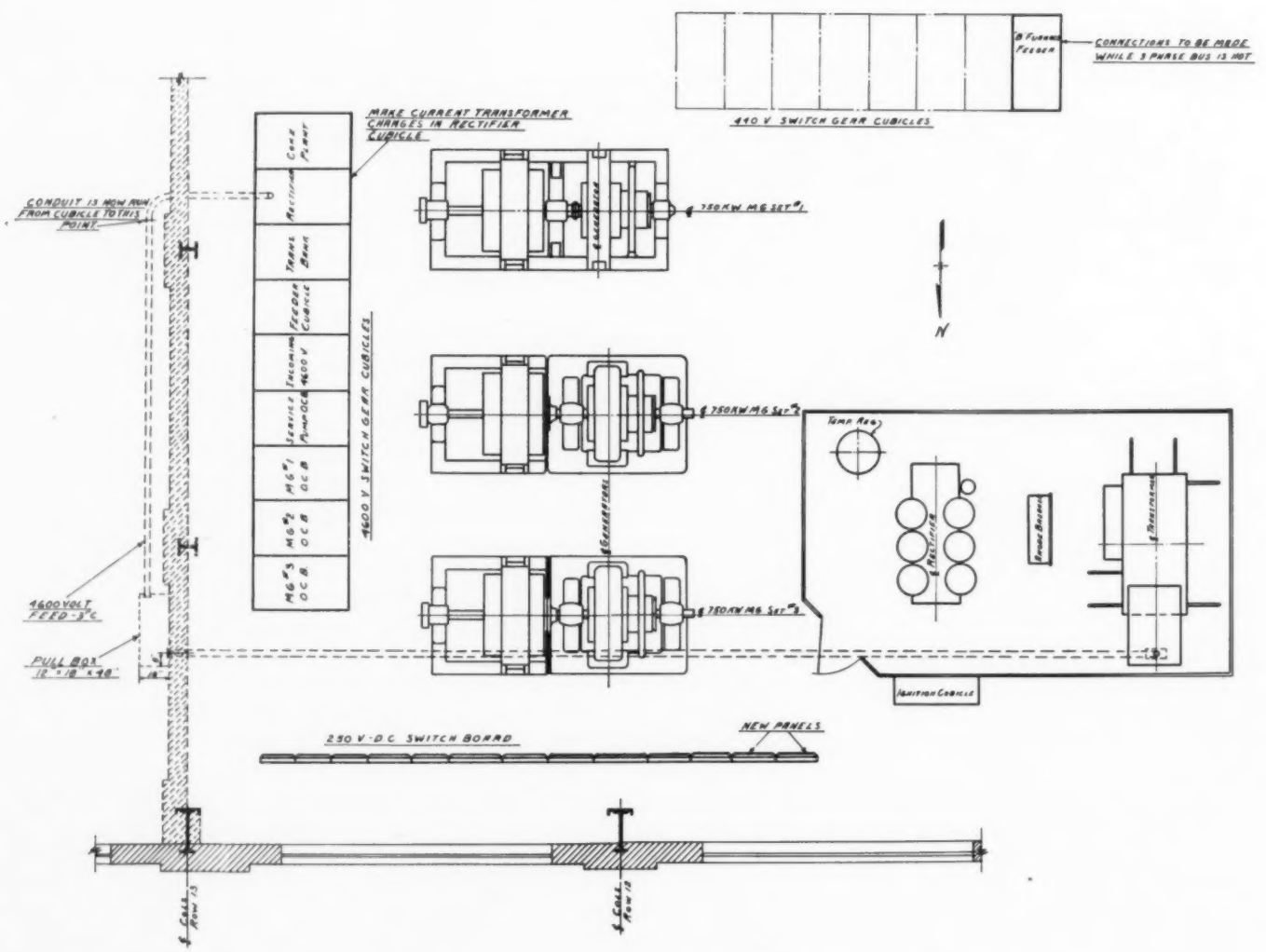
**Great Lakes Steel Corp.**

ECORSE, MICHIGAN

Presented before A. I. S. E.
DETROIT DISTRICT SECTION

*. . . . mercury-arc rectifier successfully operated in parallel with motor generator set . . . . results indicate practice deserves expansion . . . .*

**Figure 1 — Plan showing relative location of switchgear, motor generator sets and rectifier.**


440 V SWITCH GEAR CUBICLES
CONNECTIONS TO BE MADE WHILE 3 PHASE BUS IS HOT
MAKE CURRENT TRANSFORMER CHANGES IN RECTIFIER CUBICLE
CONDUIT IS NOW RUN FROM CUBICLE TO THIS POINT
4600 V SWITCH GEAR CUBICLES
750 KW M-G SET #1
750 KW M-G SET #2
750 KW M-G SET #3
N
4600 VOLT FEED - 3 C
PULL BOX 12" x 18" x 9"
230 V-D-C SWITCH BOARD
NEW PANELS
IGNITRON CUBICLE

▲ THERE are three companies in the United States building rectifiers, all making good equipment. Engineers representing each of these three companies have published very detailed papers pertaining to rectifier construction and operation. Here is a list of four such papers which have been printed in the Yearly Proceedings of the Association of Iron and Steel Engineers. They are as follows:

"Mercury Arc Rectifiers for Steel Mill and General Industrial Application," by W. E. Gutzwiller and R. W. Davis, Allis-Chalmers Company. 1932-34 Year Book, page 34.

"First Power Rectifier in an American Steel Mill," by W. E. Gutzwiller. 1938 Year Book, page 336.

"D-c Power Supply for Steel Mill Application," by W. B. Snyder and C. C. Herskind, General Electric Company. 1938 Year Book, page 442.

"Low Voltage Rectifier for Industrial Requirements," by G. E. Stoltz and J. H. Cox, Westinghouse Electric

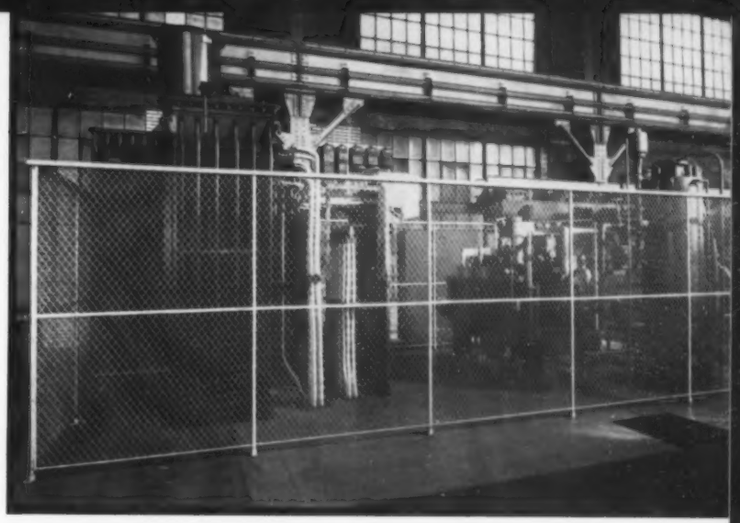
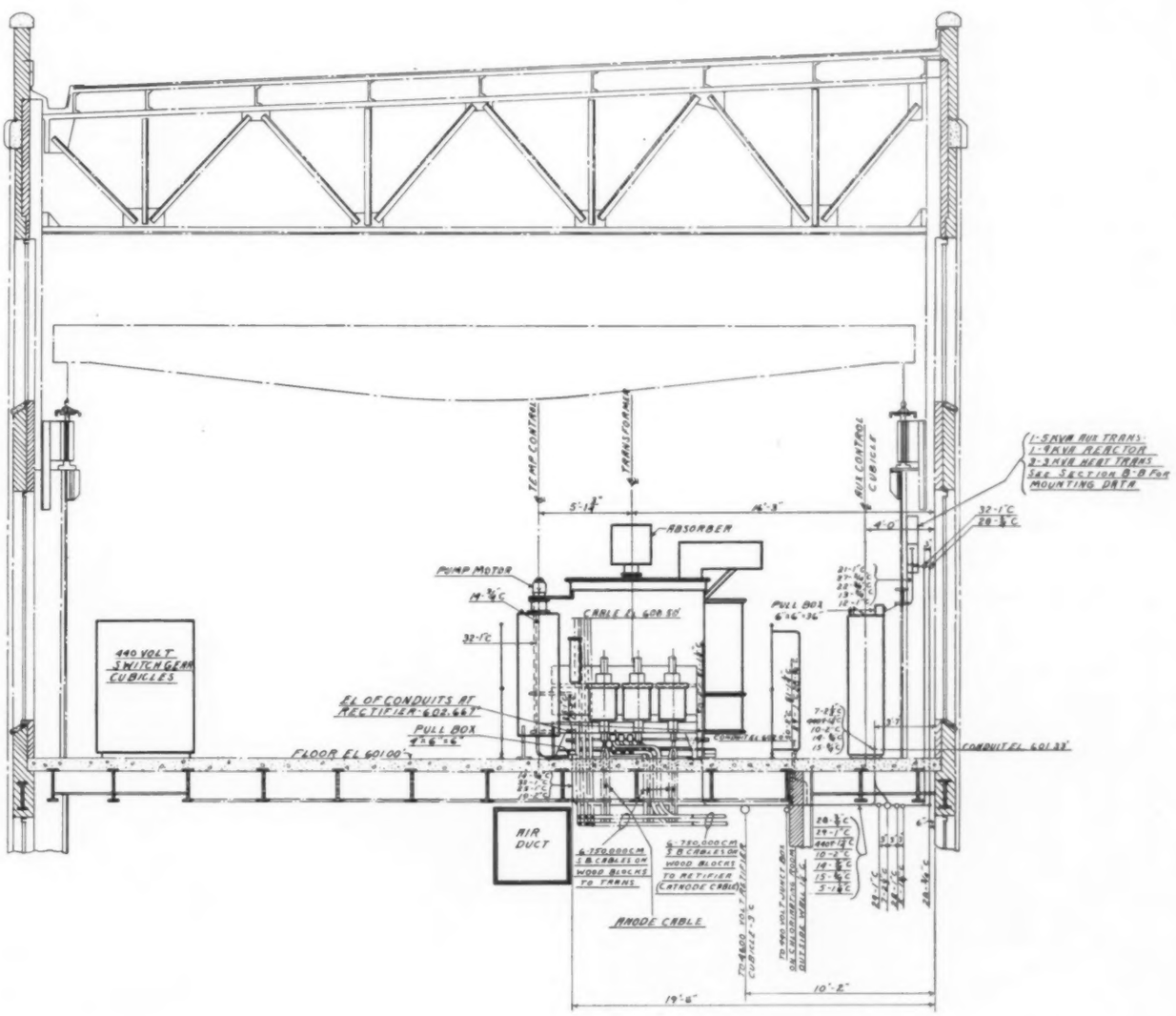


**Figure 2 — View showing rectifier transformer, with rectifier in background and heat exchanger at extreme right.**

▲

**Figure 3 — Cross-section through building, showing location of rectifier and transformer.**



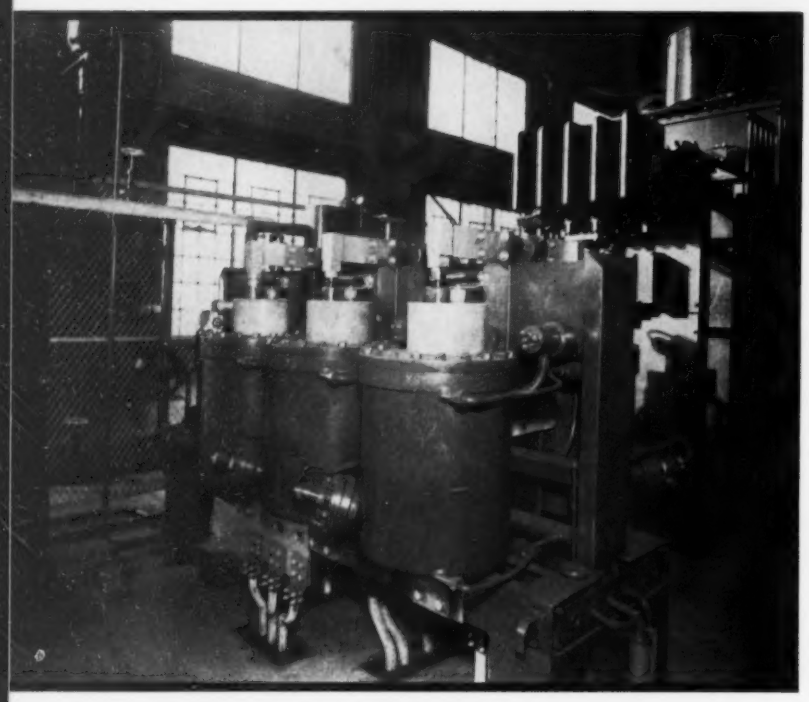


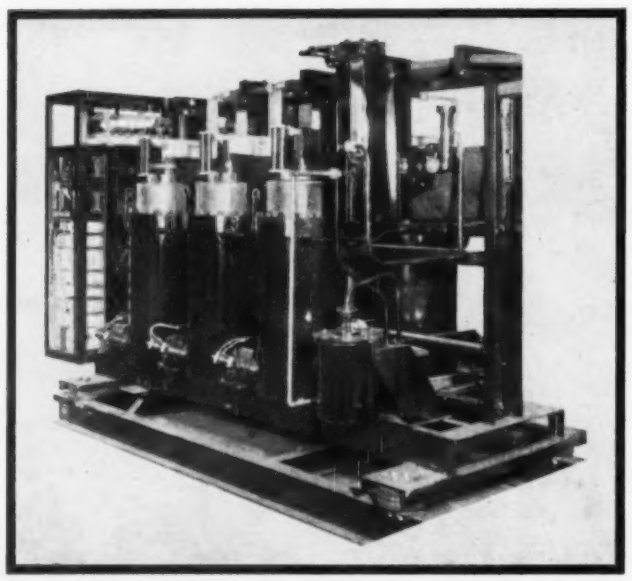
**Figure 4 — This view shows the rectifier with anode breaker in the rear, with heat exchanger on the left.**

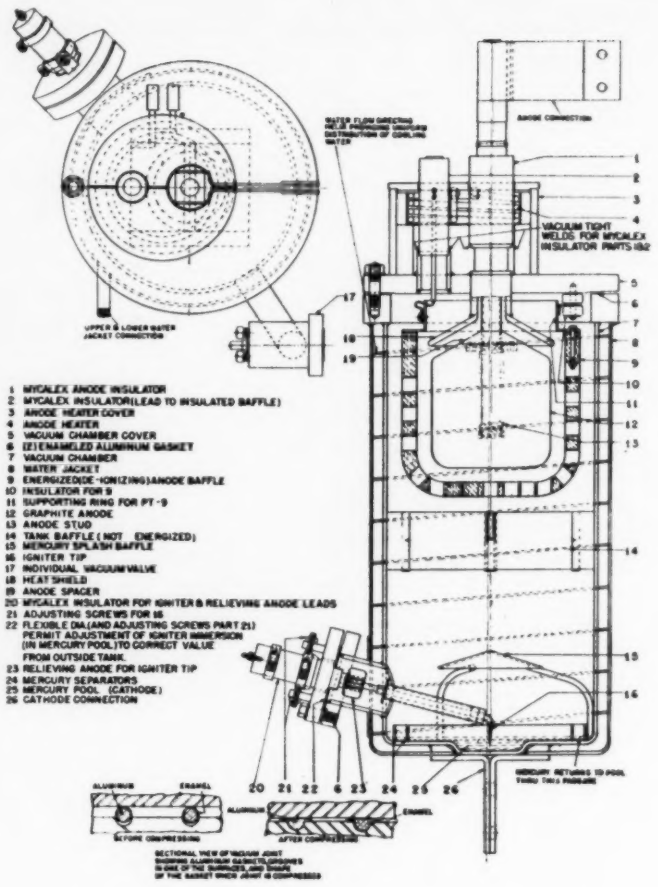
and Manufacturing Company. 1938 Year Book, page 662.

These papers describe the principal functions and operations of a rectifier far better than I could ever hope to. I will, therefore, confine my paper to an installation of a rectifier unit and try to show you where it was to our advantage to install such a unit for supplying direct current, or unidirectional, constant potential power.

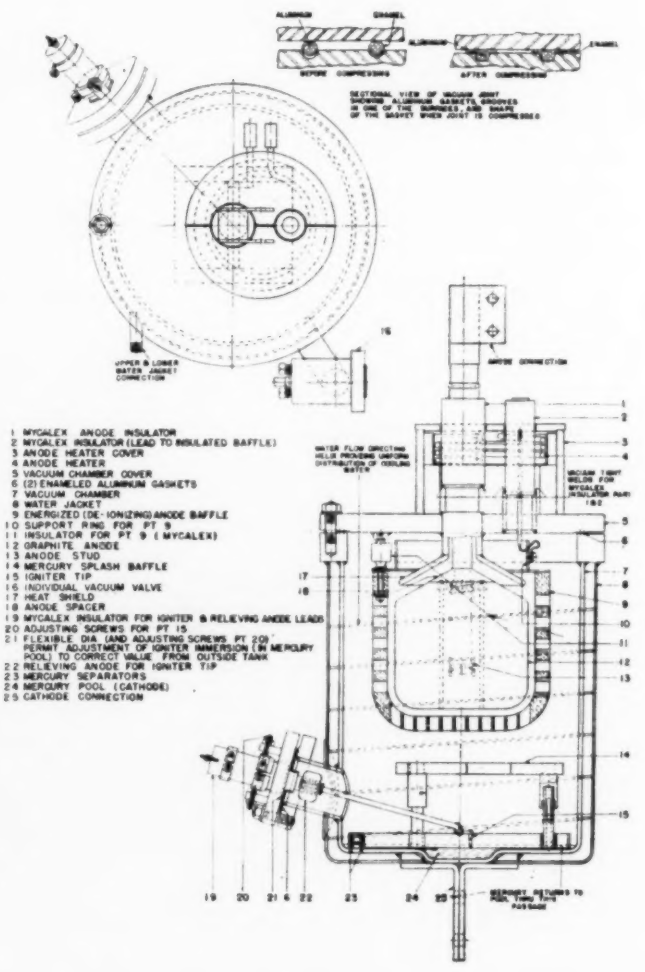
During the year 1940 and carrying on into the year 1942, we started an improvement and enlarging pro-

**Figure 5 — View of a six-tank mercury-arc rectifier, showing mercury-condensation-type and rotary vacuum pump assemblies.**




1 MYCALEX ANODE INSULATOR
2 MYCALEX INSULATOR(LEAD TO INSULATED BAFFLE)
3 ANODE HEATER COVER
4 ANODE HEATER
5 VACUUM CHAMBER COVER
6 (2) ENAMELED ALUMINUM GASKET
7 VACUUM CHAMBER
8 WATER JACKET
9 ENERGIZED(DE-IONIZING)ANODE BAFFLE
10 INSULATOR FOR 9
11 SUPPORTING RING FOR PT-9
12 GRAPHITE ANODE
13 ANODE STUD
14 TANK BAFFLE (NOT ENERGIZED)
15 MERCURY SPLASH BAFFLE
16 IGNITER TIP
17 INDIVIDUAL VACUUM VALVE
18 HEAT SHIELD
19 ANODE SPACER
20 MYCALEX INSULATOR FOR IGNITER & RELIEVING ANODE LEADS
21 ADJUSTING SCREWS FOR 18
22 FLEXIBLE (DIA.(AND ADJUSTING SCREWS PART 21) PERMIT ADJUSTMENT OF IGNITER IMMERSION (IN MERCURY POOL) TO CORRECT VALUE FROM OUTSIDE TANK.
23 RELIEVING ANODE FOR IGNITER TIP
24 MERCURY SEPARATORS
25 MERCURY POOL (CATHODE)
26 CATHODE CONNECTION
ANODE CONNECTION
VACUUM TIGHT WELDS FOR MYCALEX INSULATOR PARTS 1&2
UPPER & LOWER WATER JACKET CONNECTION
ALUMINUM
ENAMEL
BEFORE COMPRESSING
AFTER COMPRESSING

**Figures 6 and 7 — Typical plan, elevation and vertical section of mercury-arc rectifiers with listings of parts.**


1 MYCALEX ANODE INSULATOR
2 MYCALEX INSULATOR (LEAD TO INSULATED BAFFLE)
3 ANODE HEATER COVER
4 ANODE HEATER
5 VACUUM CHAMBER COVER
6 (2) ENAMELED ALUMINUM GASKETS
7 VACUUM CHAMBER
8 WATER JACKET
9 ENERGIZED (DE-IONIZING) ANODE BAFFLE
10 SUPPORT RING FOR PT 9
11 INSULATOR FOR PT 9 ( MYCALEX)
12 GRAPHITE ANODE
13 ANODE STUD
14 MERCURY SPLASH BAFFLE
15 IGNITER TIP
16 INDIVIDUAL VACUUM VALVE
17 HEAT SHIELD
18 ANODE SPACER
19 MYCALEX INSULATOR FOR IGNITER & RELIEVING ANODE LEADS
20 ADJUSTING SCREWS FOR PT 15
21 FLEXIBLE DIA (AND ADJUSTING SCREWS PT 20) PERMIT ADJUSTMENT OF IGNITER IMMERSION (IN MERCURY POOL) TO CORRECT VALUE FROM OUTSIDE TANK
22 RELIEVING ANODE FOR IGNITER TIP
23 MERCURY SEPARATORS
24 MERCURY POOL (CATHODE)
25 CATHODE CONNECTION
ANODE CONNECTION
VACUUM TIGHT WELDS FOR MYCALEX INSULATOR PARTS 1&2
UPPER & LOWER WATER JACKET CONNECTION

gram at our blast furnace plant on Zug Island in Detroit. This program consisted of the following additions to plant equipment:

New sintering plant.

Two new ore transfer cars.

Increasing our coal handling and storage equipment to twice its former size.

A new "B" furnace, about which most of you have doubtless read.

A new 10-ton ore bridge. This summer we will operate three 10-ton bridges, two 9-ton bridges, and two 5-ton bridges at this furnace plant.

A general overall speeding up of all existing plant equipment.

Blast furnace dry blast equipment.

A thickener to salvage flue dust from the blast furnace gas washer water.

We analyzed this increase of plant equipment and realized at once that we would have to augment our direct current power generating capacity.

At that time our blast furnace plant d-c load was supplied by three 750 kw, 250 volt, d-c generators, each driven by an 1100 hp, 4600 volt, 3 phase, 60 cycle synchronous motor. Two of these generators were about twenty years old, the other about two. During the boat season, we were forced to operate all three motor generator sets to supply sufficient power to operate the plant and to unload ore boats at the same time. This condition allowed us no standby capacity at all. Therefore, we deemed it a vital necessity to have one additional generating unit of not over 1000 kw capacity,

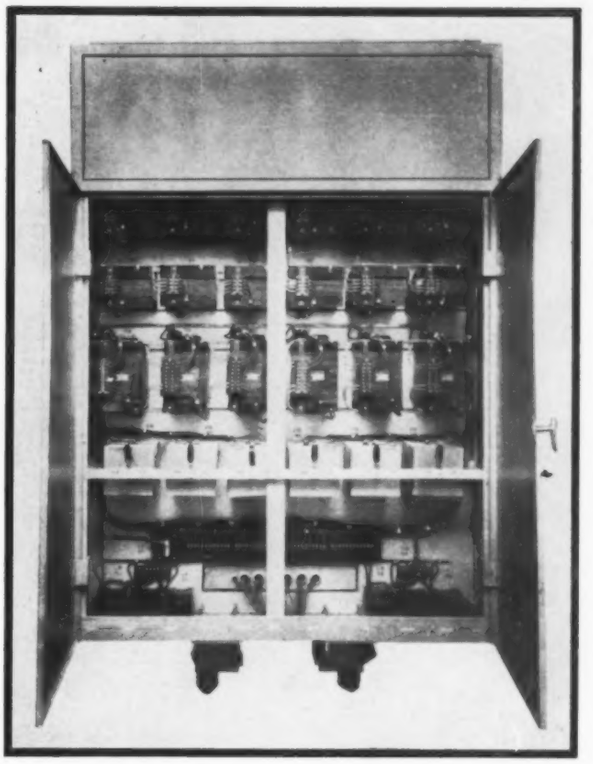
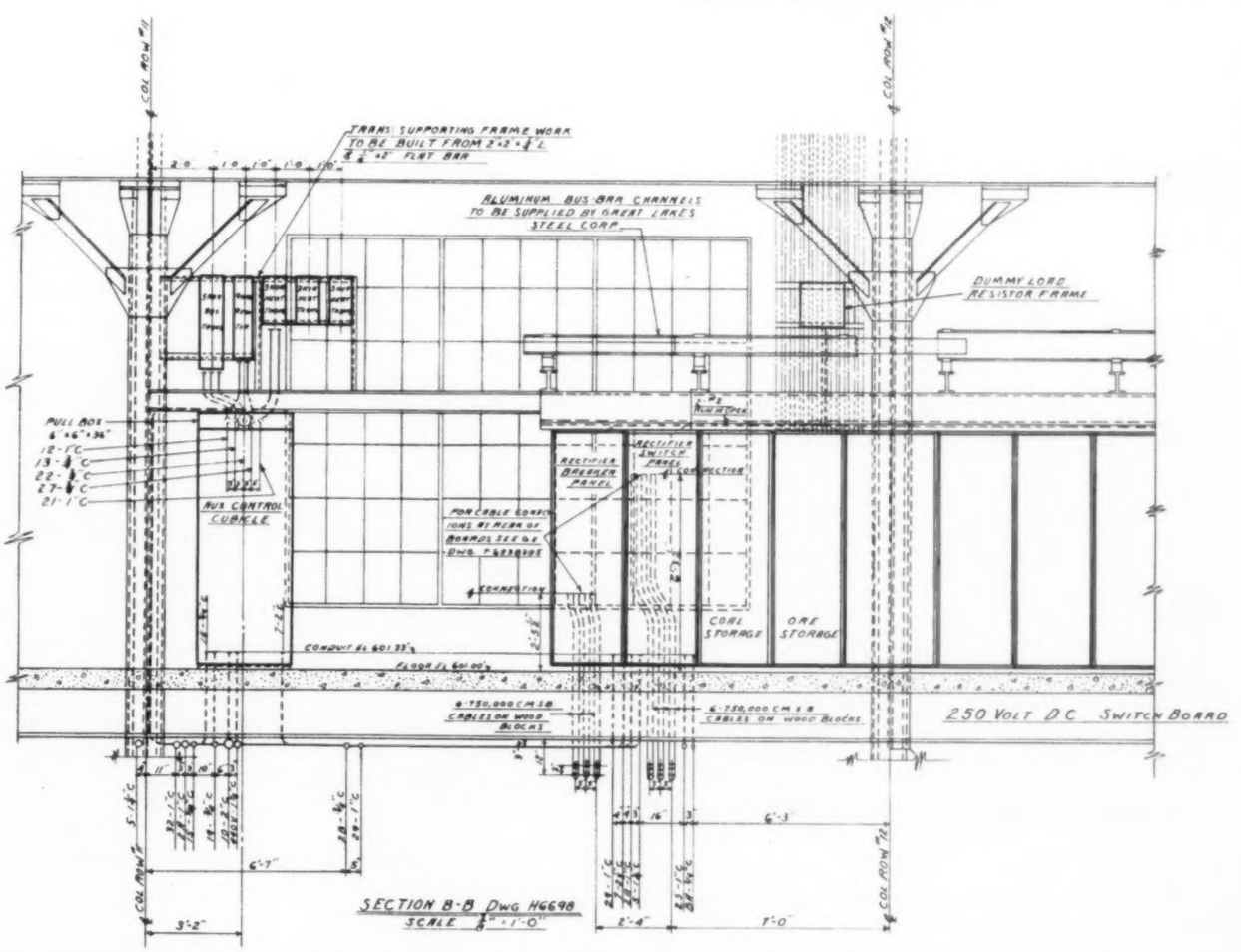


**Figure 8 — Photograph showing rear view of excitation control panel.**

▲

**Figure 9 — Drawing of building showing location of d-c panels and control cubicle.**



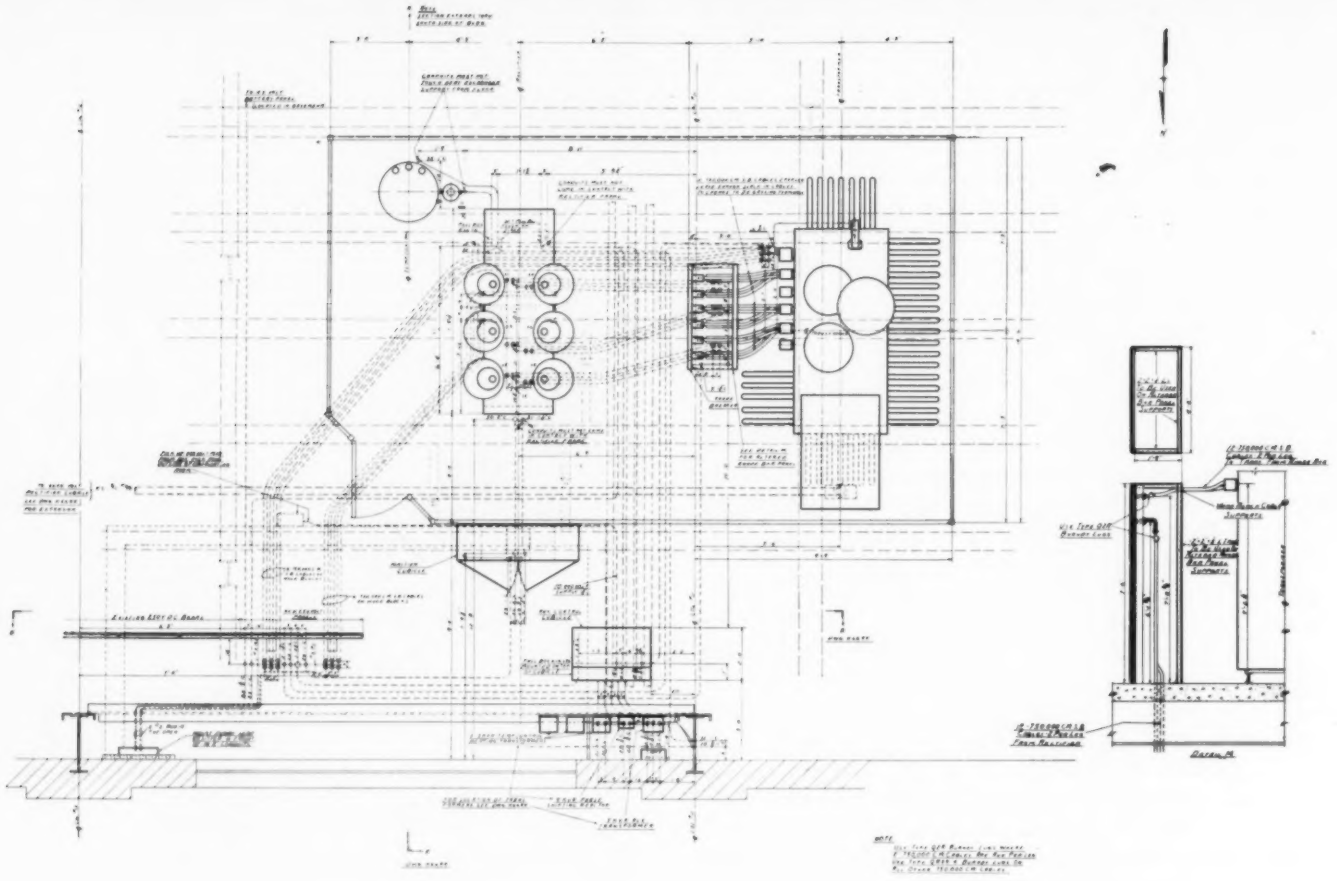
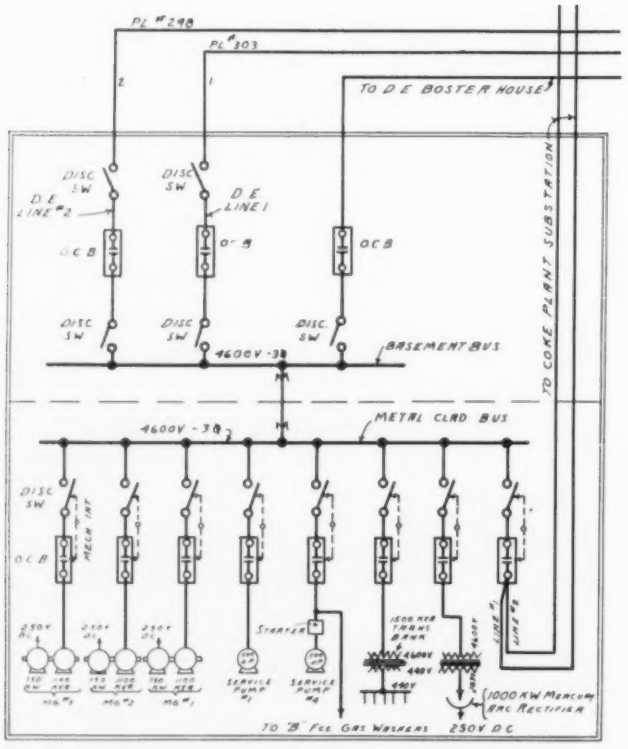


**Figure 10 — Conduit diagram of rectifier transformer.**

▲




BLOWER HOUSE SUB STATION

**Figure 11 — Line diagram of 4600 volt service.**

which would allow us to hold one machine in reserve at all times.

Our engineering department had been making a study of the mercury arc rectifier for the past five years, and had now decided that the rectifier was here to stay and also here to perform reliably. However, we had not up to this time found the spot to try out such a machine. This increased blast furnace plant load gave us the idea that at last we had such a place to try a rectifier providing the cost was within reason. To determine this fact we set up the following ten conditions to satisfy ourselves as to the total cost of the rectifier as compared with the motor generator set:

1. Purchase price.
2. Floor space required.
3. Foundation.
4. Operating efficiency.
5. Time to make complete installation.
6. Maintenance.
7. Overload capacity.
8. Ability of unit to handle extreme power peaks.
9. Ability of unit to work in parallel with existing units in any combination.
10. Cooling requirements.

*Purchase price* — The mercury arc rectifier purchase

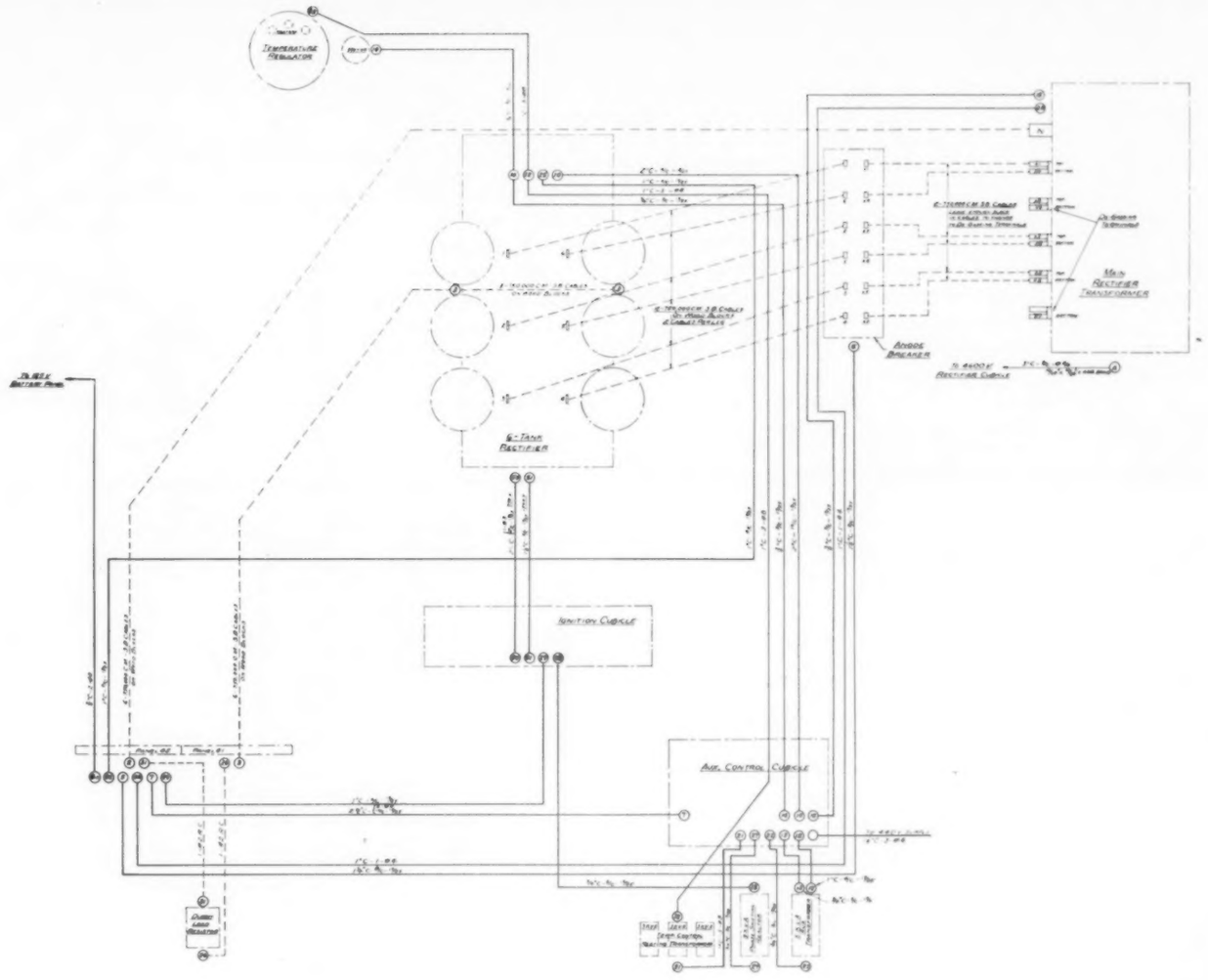



**Figure 12 — Conduit diagram for rectifier installation.**

price was several thousand dollars more than for the motor generator set.

*Floor space* — The rectifier required slightly more floor space than the motor generator set. However, this is of slight consequence.

*Foundations* — The rectifier required no foundation and could be located inside the existing blowing engine house; whereas, the motor generator set would require a foundation and also a building extension to house same.

*Efficiency* — The rectifier has a better efficiency curve on a fluctuating load such as a blast furnace plant produces.

*Time* — Since the rectifier could be installed in the present building, the time to make a complete installation would be much less as we would not have to wait for the completion of a building extension before starting the installation of the electrical equipment.

*Maintenance* — The only unit of the rectifier which moves or rotates is the small motor-driven vacuum pump. There is exceedingly little about the rectifier that can cause maintenance men any trouble. Whereas, the motor generator set has large rotating elements, three or more large bearings, and the commutator of the generator is a continuous source of trouble in the blast furnace atmosphere.

*Overload capacity* — The overload capacity of the generator is limited to the hot spots in the generator armature, commutator, and the field coils. Whereas, the overload capacity of the rectifier is limited only by the amount of cooling water used, and the capacity of the transformer. However, both the motor-generator set and the rectifier are each rated at 125 per cent capacity for two hours' duration.

*Extreme power surges* — Extreme power surges on the generator cause excess sparking of the commutator, which in turn causes excess wear of this unit. Whereas, extreme power peaks seem to have no effect on the rectifier.

*Parallel operation* — We know from past experience and operating data where proper voltage regulators are installed there is no trouble in operating motor generator sets in parallel with other sets. This was one point of comparison where we could not show anything in

favor of the rectifier. The fact is, this was the first case in the history of rectifiers where a request was made on the supplier that the rectifier should work in perfect parallel with the existing motor generator sets in any combination of units, even though these sets would be located adjacent to the rectifier and connected to the same bus. On this point of parallel operations we had to take the word of the manufacturer's agent that it would work.

*Cooling* — The motor generator set would require large quantities of air for cooling as well as duct work and air cleaners. The air about a blast furnace and coke plant is not the best in the world for cooling generators due to the sulphur in the atmosphere, which attacks the copper. Here the rectifier had a big advantage as the only cooling medium required was a small amount of river water passed through a heat exchanger; namely, 35.4 gallons per minute during the warmer months.

Having made this comparison, we found that the rectifier would be the best unit to install, as the over-all cost would be less, maintenance would be less, operating efficiency would be better, and it would take less time to make the installation.

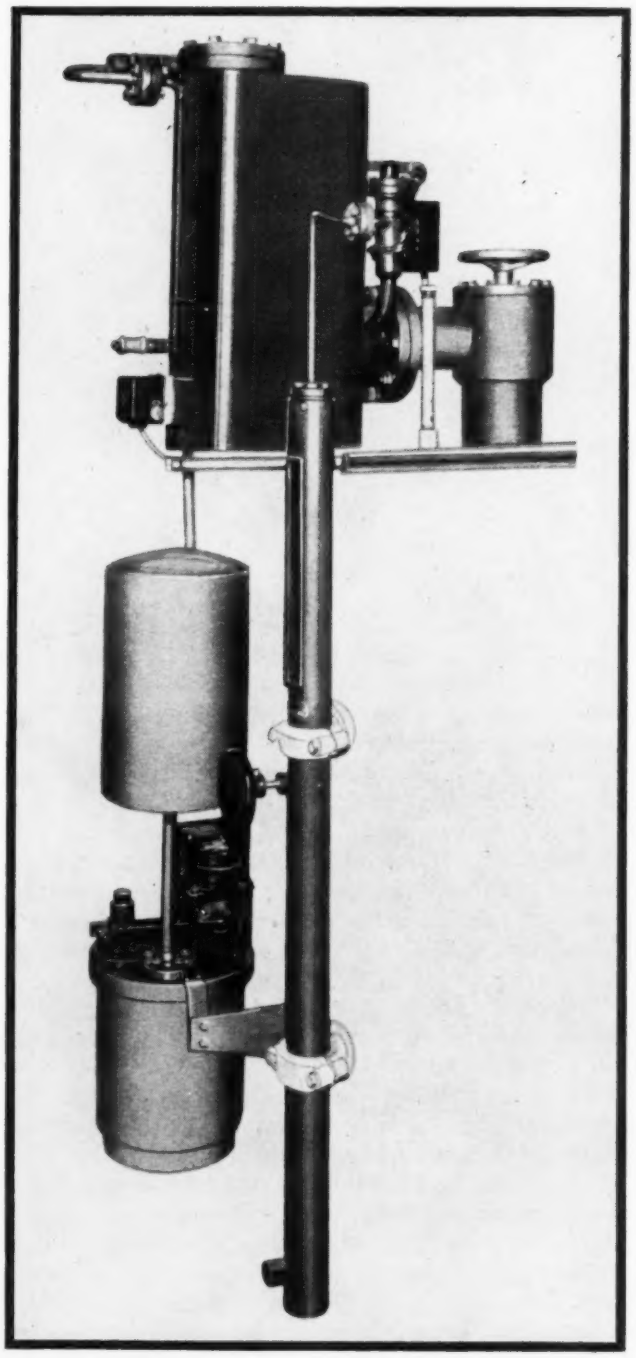
### Rectifier Unit Equipment

At this point it might be well to list the equipment comprising the rectifier unit and give a description of each item.

*Primary oil circuit breaker* — In this case this breaker is of the cubicle type, 4600 volt, 3 phase, 60 cycle, and has an interrupting capacity of 250,000 kva. It is located in our 4600 volt bus structure. This breaker serves as the source of supply.

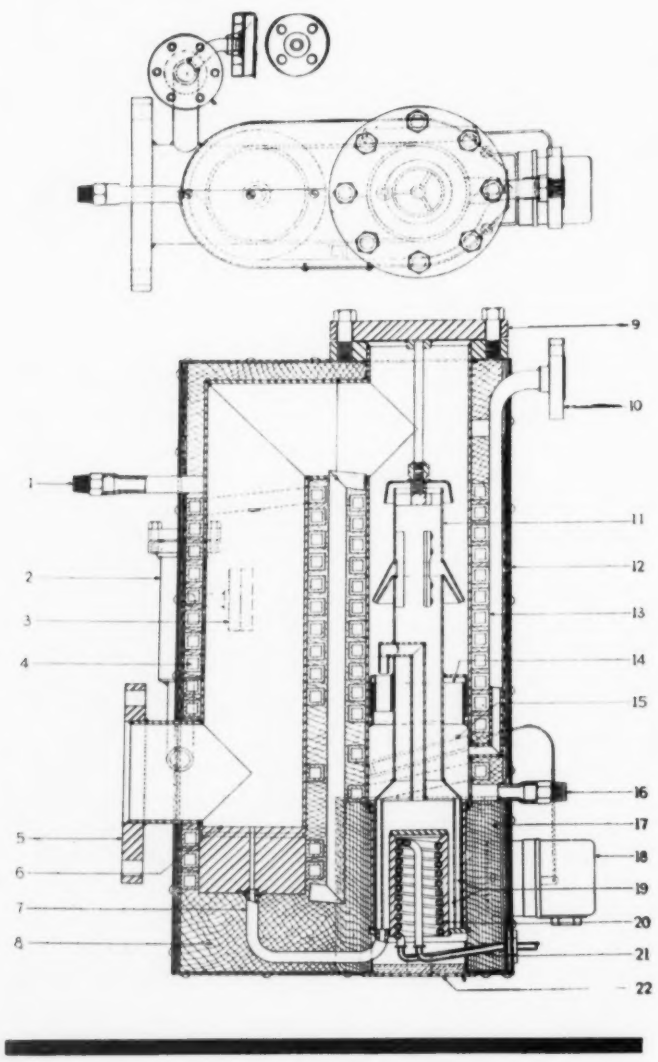
*Transformer* — The transformer, rated 1190 kva, 4600

**Figure 14 — View of exhaust system for mercury-arc rectifier using mercury vapor vacuum pump.**



▲

**Figure 13 — Cross-section through the mercury vapor vacuum pump.**



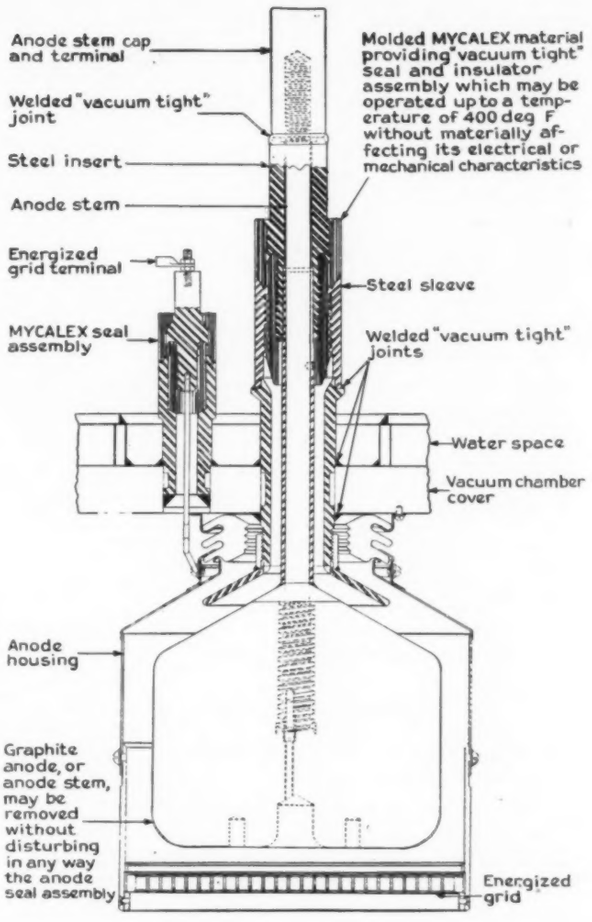
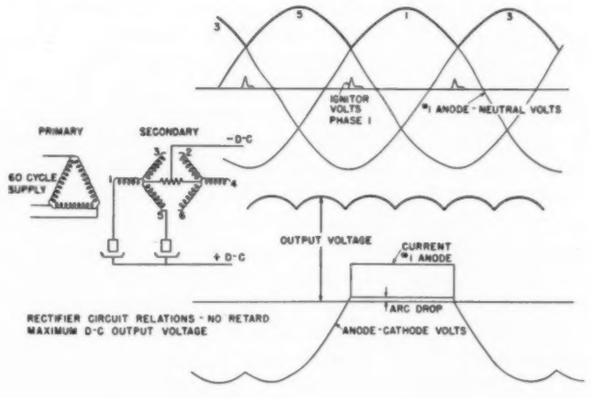

Anode stem cap and terminal
Welded "vacuum tight" joint
Steel insert
Anode stem
Energized grid terminal
MYCALEX seal assembly
Anode housing
Graphite anode, or anode stem, may be removed without disturbing in any way the anode seal assembly
Molded MYCALEX material providing "vacuum tight" seal and insulator assembly which may be operated up to a temperature of 400 deg F without materially affecting its electrical or mechanical characteristics
Steel sleeve
Welded "vacuum tight" joints
Water space
Vacuum chamber cover
Energized grid

**Figure 15 — Insulated grid, anode and seal construction for metallic tank mercury arc rectifier.**

▲

**Figure 16 — Silograph curve of rectifier voltage with no retarding.**



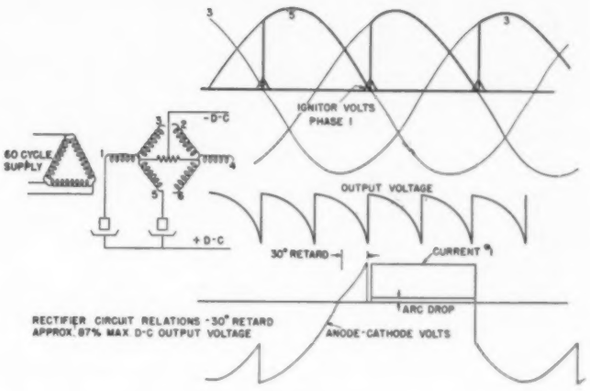




**Figure 17 — Silograph curve of rectifier voltage with 30 degree retarding.**

volt, 3 phase, 242 volt, 6 phase, is used to change the phase as well as step down the voltage for the rectifier. The transformer is fireproof, liquid cooled, with built-in surge protectors. It has a high-voltage pot head and cable terminal box located on the end with an explosion relief tank located on top. The low voltage leads are brought out through the side near the top of the tank.

*Anode breaker* — The anode breaker is a 6-pole, 250 volt, motor-operated air breaker. Each pole can be tripped independently. There is one pole for each rectifier tank. When this breaker is opened, the rectifier is disconnected from the transformer. It also serves to isolate individual tanks should one backfire and thus allows the other five tanks to carry the load until the fault is corrected.

*Mercury arc rectifier* — The rectifier proper consists of an insulated framework upon which is located six steel tanks, each sealed up air tight, and all connected to a pipe header, which is in turn connected to vacuum pumps. One pump is motor-driven; the other is operated by mercury vapor. These two pumps are capable of maintaining a vacuum of two microns of pressure, which is equal to 29.3992 inches of mercury at this elevation. These tanks are about 15 inches in diameter by 30 inches high, and each contains a small pool of mercury.

Sealed into the top of each tank is a carbon electrode called the anode. The mercury is called the cathode. The anodes are connected to the 6-pole air circuit breaker.

The current passes through the tank from anode to cathode by means of an electric arc. This arc is started by a small anode which is located near the pool of mercury, and once the arc is started, this starting anode is cut out of the circuit.

This arc inside the tank generates heat, and to keep the tanks at a proper temperature, they are water-cooled by copper coils surrounding the tanks. These coils are connected to a heat exchanger.

*Firing cubicle* — This unit is used to control the se-

quence of firing of the tanks and to control their proper operations.

*Control cubicle* — This cabinet controls all the auxiliaries of the rectifier.

*D-c panels* — These panels are necessary to connect the rectifier to the d-c bus located above the panels. They have the same functions as any generator breaker panel.

This unit, less transformer, was tested at the factory by a 3000 kw continuous load for 48 hours, and since its installation it has carried loads of 1250 kw for periods of 2½ hours duration without showing signs of trouble.

Time after time I have seen this machine carrying peak loads of 175 per cent of full load without undue voltage droop. In other words, it has proven that the rectifier can "take it" and still stay on the line and ask for more. The only limit to the ability of this machine to take and carry load is the load limit built into the transformer.

This rectifier unit went into service about November 15, 1941, and has met all our requirements for a constant potential d-c auxiliary power generating unit. It has paralleled perfectly with the existing motor generator sets and can be made to take any part of the total station load that the operator wishes. We believe this unit is the forerunner of many such installations in the near future.

# DISCUSSION

PRESENTED BY


D. E. RENSHAW, Industry Engineering Department, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania

C. M. DAVIS, Sales Engineer, Allis-Chalmers Manufacturing Company, Detroit, Michigan.

W. A. MOSTELLER, Control Engineer, General Electric Company, Detroit, Michigan

L. R. MILBURN, Electrical Engineer, Great Lakes Steel Corporation, Ecorse, Michigan

W. H. CLARK, Great Lakes Steel Corporation, Ecorse, Michigan.

A. W. MOHRMAN, Electrical Superintendent, Great Lakes Steel Corporation, Ecorse, Michigan

A. J. F. MAC QUEEN, James Stewart, Inc., Chicago, Illinois.

W. E. REIBER, Assistant Chief Electrician, Great Lakes Steel Corporation, Ecorse, Michigan

GEORGE GABOR, Repairman, Great Lakes Steel Corporation, Ecorse, Michigan.


D. E. RENSHAW: I have listened very carefully to Mr. Milburn's paper and I was very much impressed with the careful ten-point analysis he made and the conclusions that he reached in regard to the use of the rectifier for this type of service. I really was hunting for something to argue about. I had a little trouble finding anything to disagree with.

There is one little phrase I want to argue with Mr. Milburn about: He said they had tried to find a place to try out a rectifier. Those are the words, "try out" that I challenge. The conventional-type rectifier and the ignitron type rectifier have both passed the try-out stage. I admit there might be some instance of trying out such a rectifier in a particular type of service to which it has not been previously applied, but the rectifier itself has been proved by years of experience.

I have some data which tends to confirm the decision reached by Mr. Milburn to use the rectifier instead of the motor generator set.

Figure 1 shows the relative efficiencies and losses of a 1500 kw, 250 volt d-c rectifier as compared with the losses of a correspondingly rated motor generator set. For example, in a 1500 kw installation operating at 60 per cent load factor, there is a difference in losses of 52 kw. This means that, for every hour of operation, there is a saving of 52 kwhr through the use of rectifiers.

Table I is an economic comparison of a 1500 kilowatt rectifier against a 1500 kilowatt rotating machine. The assumed load factor is 60 per cent. This was derived from a study of a duty cycle which was outlined by an operator, and it appears from this duty cycle that the load factor would be 60 per cent. The power cost per kilowatt hour, based on 60 per cent load factor, is 8 mils. The excess loss of the motor generator set is 52 kilowatts. The assumed saving, as indicated here is $2905, by use of the rectifier instead of the motor generator set. That is an assumed figure, as I say, but personally I believe that saving is much too low when compared with actual operating figures.

I have some approximate information on quite a

**TABLE I**

**Economic comparison of rectifier versus motor-generator set**

| | |
|---|---|
| Kw rating | 1500 |
| D-c voltage | 250 |
| Hours operation | 6500 |
| Load factor | 60% |
| Power cost per kwhr at 60 per cent load factor | 0.008 |
| Excess of kw loss in motor generator set at 60 per cent load factor | 52 |
| Excess of kwhr loss in motor generator set at 60 per cent load factor (52 x 6500) | 338,000 |
| Yearly cost of excess loss in motor generator set | $2705 |
| Assumed annual saving in maintenance of rectifier over motor generator set | $100 |
| Assumed annual saving in attendance of rectifier over motor generator set | $100 |
| Cooling water rectifier | ... |
| Power for ventilation of motor generator set | ... |
| Total annual operating saving in favor of rectifier | $2905 |
| Fixed charge rate | 12% |
| Capitalized value of saving: $2905 ÷ .12 | $24,200 |

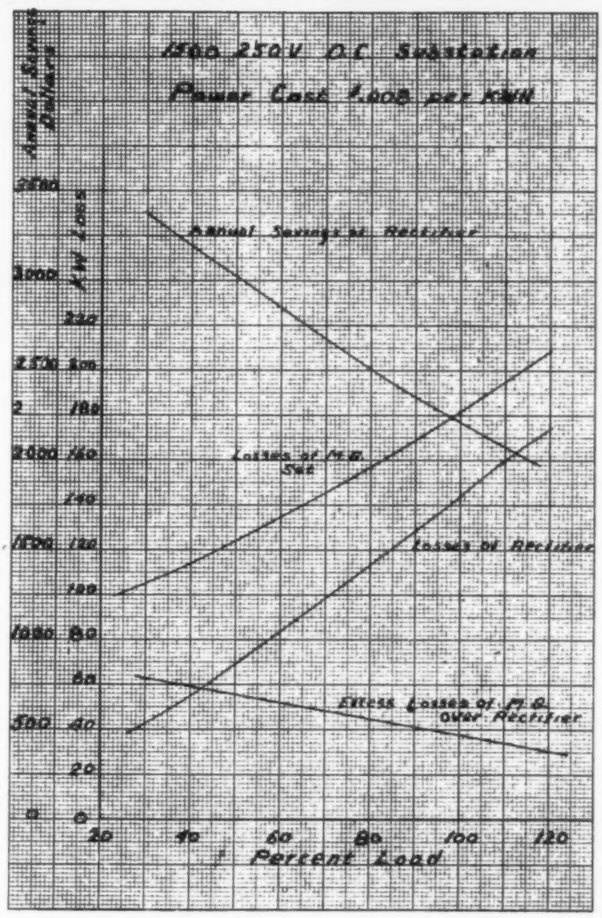



**Figure 1 — Efficiencies and losses of rectifier and motor-generator set.**

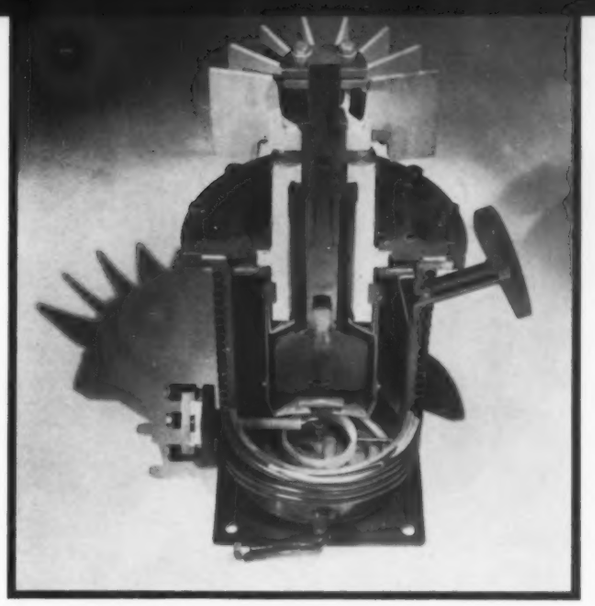


**Figure 2 — Cut-away view of ignitron.**

**Figure 3 — Air cooled rectifier transformer with covers removed.**

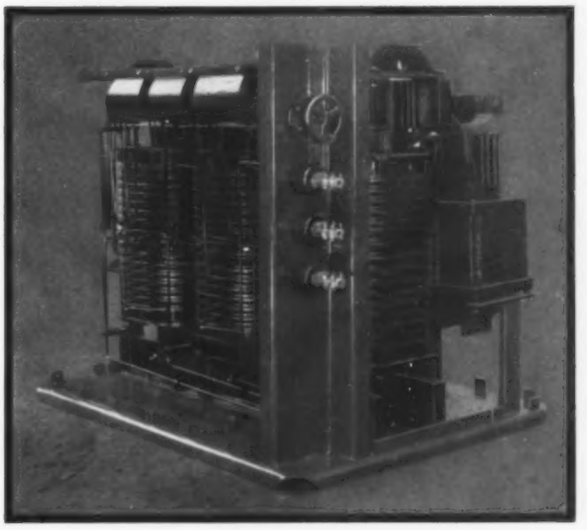
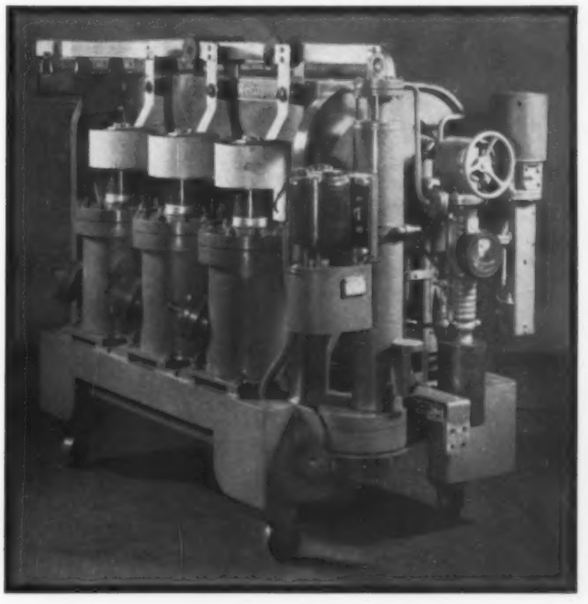


**Figure 4 — Mining type ignitron rectifier of 300 kw capacity.**



number of smaller rectifier installations in coal mines. These rectifiers, of the single anode ignitron type, of which there are from twenty to twenty-five outfits in service — I can say with perfect honesty — are operating with a maintenance expense of not more than $15.00 a year. These rectifiers average about 400 kilowatts capacity, but whether the rating is 600 or 1000 kilowatts, the maintenance expense would be exactly the same, because the maintenance would not vary whether it is a small set or a large set.

You and I know perfectly well that $15.00 is a false figure because, after a period of years there, a major overhaul may be necessary. For example, it may become necessary to open up the tanks to remove mercury oxide, which may be formed as a result of slow leakage of air into the tanks. When that time comes, there will be considerable expense — $100, $200, $300 required to put that rectifier back to work. But, I believe that this difference in the maintenance expense gives the motor generator set all the best of it, even assuming that the saving of maintenance expense of rectifiers over motor generator sets to be $100. That figure is possibly accurate, but I still think that gives the motor generator set the best of it, because these

**Figure 5 — Two 400 kw rectifiers and automatic switching for mining service.**

So, the total annual saving of the rectifier is $2905, and this amount capitalized at 12 per cent is equal to $24,200. Since the installed cost of a 1500 kw rectifier is approximately the same as for a 1500 kw motor generator set, this saving in operating cost is almost all velvet.

Figure 2 shows a cut-away of an ignitron rectifier. At the top is a finned type anode radiator, above a porcelain anode bushing. The top plate has a cooling water coil and the tank is jacketed by a spirally wound, welded-on copper coil. Around the anode is a shield of a type suitable for the particular service involved. At the lower left is the ingitor bushing, and at the right is the vacuum system connection. The cooling coil in the bottom of the tank is normally covered by the mercury pool cathode.

I show the picture (Figure 3) because it illustrates a type of transformer different from that which was used in Mr. Milburn's installation. This is an air-cooled transformer which was made for the same type of service; in other words, for indoor service for which flame-proof, liquid filled transformers have been used. It lends itself very well to the surrounding conditions. The three high-tension leads and the tap changer handle are shown on the near end.

Figure 4 is the photograph of the rectifier which is fed by the transformer in Figure 3. This may be of some interest to the steel industry because this particular rectifier goes some 2,000 feet under ground in an iron mine.

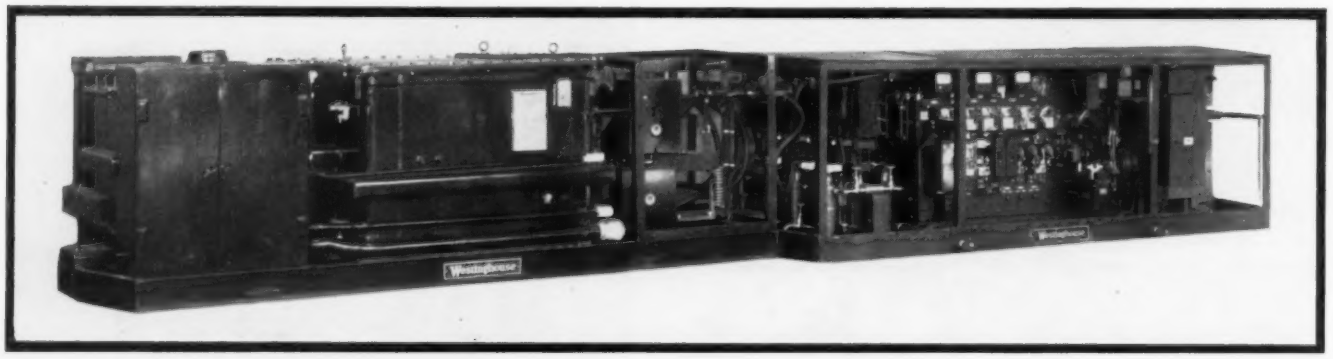


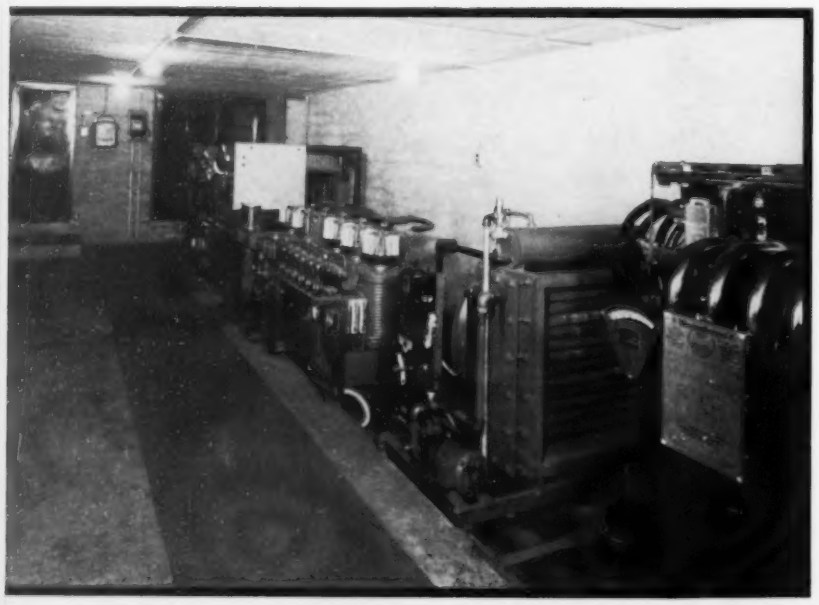
**Figure 6 — Portable truck mounted rectifier.**

Mr. Milburn mentioned that the rectifier could go into an existing building without adding to it. Figure 5 tends to illustrate that same point, although this set-up did not go into an existing building, but here are two 400 kilowatt, 600 volt rectifiers, which are placed in a building which is a little more than an oversize sheet steel garage. They are set on a thin concrete slab since there is no great weight to support. As a matter of fact, those rectifiers could stand on a table without breaking it down.

Figure 6 is not a steel mill type of assembly by any stretch of the imagination. This happens to be a portable rectifier used in a coal mine. The small a-c switching is mounted on one car. These are four-wheel cars. The rectifier and d-c switching is on the other car. This unit is rated approximately 1100 amperes. The maximum height of that particular unit overall is 46 inches,

20 to 25 smaller sets get an average of about fifteen minutes a week for attendance. As far as cooling water is concerned, there is no expense placed on that in this comparison because it was thought that that would balance the power for ventilation of the motor generator set.

**Figure 7 — Underground rectifier substation.**



which indicates the extreme flexibility of arrangement that can be obtained by a rectifier of that rating — without excessive weight or excessive size.

Figure 7 shows the first ignitron rectifier for main power service that was ever built. This was installed in a coal mine in Pennsylvania about two miles away from the shaft bottom, in a concrete-block room. In the foreground is the transformer, followed by the heat exchanger, the rectifier, the d-c switchgear, and the a-c switchgear.

**C. M. DAVIS:** I have a letter from Mr. Gutzwiller, and he mentions that he could not be present due to the pressure of work. He says: "You may state that our company has in operation and under consideration a number of the single-anode rectifiers for steel and wire mills and that there is at present a steadily increasing demand for equipment of this type for the steel industry."

"Mr. Milburn's paper contains information which should be valuable to steel operating men. It would, perhaps, be desirable to state what the actual measured over-all efficiency of the rectifier unit is: how parallel operation with motor generator sets can be accomplished, bearing in mind that the rectifier d-c voltage is directly affected by the a-c voltage changes, while the motor generator set is not."

I think Mr. Milburn can answer about the parallel operation.

**L. R. MILBURN:** A parallel operation is accomplished by the fact that on the three motor generator sets we have a counter-voltage regulator system, and we apply that same regulation to the rectifier.

The effect of voltage variation shows up with the rectifier sooner than on a motor generator set, but the phase shifting transformer on this particular installation irons out that variation due to the changing of the voltage.

Frequency variation will affect the d-c voltage more than will the variation of a-c voltage.

**C. M. DAVIS:** There is one figure I would like to have repeated. There was talk about a micron of atmosphere. I know that the ordinary layman will be interested to know that a micron is 1/760,000th of an atmosphere.

**W. A. MOSTELLER:** The rectifier at the Great Lakes blast furnace plant is used to help make steel. There is another point I would like to leave with you, and that is that the rectifiers are not used only in the steel mills. One of the other places they are used very extensively is in the chemical industry — literally hundreds of thousands of kilowatts are being installed at the present time in chemical plants and in plants which manufacture the lighter metals, such as magnesium and aluminum. These installations operate at higher voltages than the installations described by Mr. Milburn, that is about 600, and in some cases several small units are operated in parallel to give as much as 60,000 amperes. Such rectifiers are very similar to the ones such as described here. We have used in these installations the very same equipment as described, and they are connected in either the 6-phase or 12-phase relation with anode breakers, heat exchanger, and auxiliary equipment described by Mr. Milburn — all with the use of rectifiers. With such a large number of rectifier installations in the industry, we are sure that the rectifiers are here to stay.

**L. R. MILBURN:** Mr. Renshaw brought out a question as to the trying out of a rectifier. In our particular installation, I can truthfully say we were in a spot to try it out because we wanted to try working it with rotating generators. We knew we could safely use them as individual rectifiers, but we had not been definitely convinced in our own mind that a rectifier located adjacent to two or more motor generator sets would work in parallel with them. That is why we say, "we were trying it out."

**W. A. MOSTELLER:** So far Mr. Milburn hasn't brought up the question of power factor correction. I know we have put in motor generator sets with leading power factor — synchronous motors to correct power factor. How do you solve the power factor problem when rectifiers are used?

**L. R. MILBURN:** The mercury-arc rectifier will not correct power factor; and if you have a plant where you are penalized on power factor, you cannot afford to use a rectifier. Our power factor is around 92 to 94. As your load goes down, your power factor goes down, and with a very light load your power factor is low, but up to a load and a quarter, your power factor is up to 94. At this particular plant we were fortunate in having an abundance of power factor correction, and we won't be penalized as to this particular thing. Of course, in the summertime we will have a motor generator set running in addition to the rectifier and thus we can correct our power factor still more. I think we will be able to carry a power factor of 95 or better. You take a plant such as Michigan Steel and shut down your motor generator sets; with the set-up you had with those big induction motors it would not do there, because sometimes you are penalized for even trying to get a power factor that would give you your proper discount. A rectifier would aggravate that situation rather than help it.

**W. H. CLARK:** I would like to ask two questions. Mr. Milburn admitted that this rectifier costs more than a corresponding motor generator set; now, thinking in terms of asset costs and the corresponding charge to income for depreciation on the asset, I am wondering if the increased depreciation charge could eat up the performance and maintenance savings on the rectifier?

My second question is, whether rectifiers of this type have been on the market long enough to establish a life expectancy on them?

**L. R. MILBURN:** I would like to answer your last question first. I would say that the life expectancy of an arc-rectifier is far superior to the motor generator set in the atmosphere we have in our particular plant, near the location of the blast furnaces on the one side and the coke ovens on the other side. In such a location you are bound to have bad atmosphere. The atmosphere will not affect the rectifier, but it will affect the motor generator set and also the slip rings in the synchronous motors.

As to the direct price of the rectifier over the motor generator set, I do not recall the exact figures, but the data that Mr. Renshaw presented, I would say, show the savings on a very limited scale, of a small rectifier over a motor generator set, something like $2,900 in a

year, which in my estimation would vary, and would thus pay for the rectifier in a few years.

**A. W. MOHRMAN:** I have a set-up in mind, but in this particular case the motor generator sets were supplied with 2300 volts, 25 cycles, from a power house; and, when a new plant was built two miles, we will say, from that plant, power was supplied by a utility power company at 4600 volts. The power house did not have capacity enough to put motor generator sets on for more d-c power, and they had to put more motor generator sets in the new plant on the utility power line. In this case, would a rectifier on 60 cycles parallel at that distant point on d-c with the motor generator sets in the power house on 25 cycles?

**L. R. MILBURN:** I would say yes.

**A. W. MOHRMAN:** What do you use for parallel connections?

**L. R. MILBURN:** Providing you had decent regulation on the motor generator sets. If you had the old compound wound, differentially wound generators, and depended on your equalizer switch when you threw them together, you would have to trust that they would stay together long enough to get in the breaker. But I still think with the proper regulation on the generators you could use your rectifier on the new set-up if you have fairly good central station supply such as generated in this district.

**A. W. MOHRMAN:** Is an equalizer necessary?

**L. R. MILBURN:** No, no equalizer is necessary. The fact is out at Republic Steel the generators were installed in the power house a half mile away from the wire mill where they installed a rectifier, and they had a tie line in between. This tie line circuit was hot all the time although the wire mill normally took its load from the rectifier six days out of the week, except on Sunday when they would shut it down for cleaning and inspection.

**D. E. RENSHAW:** There is an installation in the course of construction for a 25 cycle plant and a 60 cycle utility supply being tied together on a rectifier, the motor generator sets on the 60 cycle supply, and the rectifier on the 25 cycle supply; and they are in parallel on the d-c side.

**L. R. MILBURN:** There is no reason why they won't parallel if you have proper voltage regulators. That is what I want to point out. With modern voltage regulators, a motor generator set and a rectifier with good voltage supply will stay together; in fact, I think we have proved it here at our blast furnace.

**MEMBER:** Have you had any trouble with the telephone system at Zug Island?

**L. R. MILBURN:** We have heard of no telephone interference. The telephone company was rather skeptical at the time, and we were doubtful because we had one telephone cable paralleling our d-c cables, but so far we have not had any intereference that I can recall.

**A. J. F. MACQUEEN:** Mr. Milburn, would a half mile between your power supply points make very much difference?

**L. R. MILBURN:** It wouldn't make very much difference. There is enough resistance in these lines to offset any variation that might be made between the rectifier and the generators.

**A. W. MOHRMAN:** How do the operators like the rectifiers as compared to the motor generator set?

**L. R. MILBURN:** Our operating department is very enthusiastic about the rectifiers as they so far have caused no trouble and require less maintenance than the motor generator sets. Should anything go wrong with the rectifier, it trips itself off the line and sounds an alarm which notifies the operator, and he immediately ascertains the trouble by checking his indicator on the firing cubicle.

**D. E. RENSHAW:** I don't think the discussion brought out the question as to whether you use treated water or raw water in your heat exchanger.

**L. R. MILBURN:** The theory of it is this: If you use raw water in this cooling coil or water jacket, it tends to leave a deposit on the walls of this jacket or copper coil, and the jacket tends to become coated the same as the tea kettle at your home where well water leaves a deposit after boiling. This takes more heat to penetrate that coating so within a short period of time you do not get the proper cooling on the tank. Therefore, we use treated water, in other words soft water, in this water jacket, and take it out through a cooling system surrounded by another jacket which is cooled by river water. The water that is used to cool the rectifier is recirculated all the time, not being contaminated by contact with air or raw water. The same thing is true around the boiler and condenser of the mercury vapor pump, all of which goes through the same exchanger and is cooled by the Detroit river water.

**W. H. CLARK:** Does it cost very much for the equipment to treat that water?

**L. R. MILBURN:** No. We use eight pounds of a sodium bichromate solution, that is five-tenths of one per cent by volume of water. This material costs us very little; in fact, the first installation was presented to us by the rectifier manufacturer; and, with proper care, this treated water can be used over and over.

**C. M. DAVIS:** I think there is one field that hasn't been covered, and that is the use of mercury arc rectifiers on a crane load; with the comparatively flat power factor on a rectifier, down to a quarter load or thereabouts, it would show up a whole lot better than on a motor generator set. In fact, I think it would show up to better advantage on any load over rotating equipment.

**L. R. MILBURN:** We tried to bring that out in the paper, that on varying loads such as a blast furnace has, or any plant with a great number of cranes, where your load factor is practically from zero up to as high as 200 per cent, the rectifier will prove very superior to any motor generator set due to the fact that it has higher efficiency on the lower load factors; and on these varying load planes the variation at the lower levels is where the efficiency can be used. I would not hesitate to put a rectifier on any crane job. That is why we put it on the blast furnace plant, due to the fact that we may have all cranes and bridges starting and digging ore at the same time.

**A. J. F. MACQUEEN:** What happens to these rectifiers when the load drops clear to zero?

**L. R. MILBURN:** When it drops to zero, there is a small dummy load resistor hooked across from the negative to the positive that puts a small ampere load on that rectifier and keeps it firing. It is very minute

however, in the neighborhood of about ten amperes, just enough to keep it firing.

**W. E. REIBER:** Could rectifiers be used in place of motor generator sets that are being used on Ward-Leonard systems such as we use on our finishing line on our No. 2 hot strip mill?

**L. R. MILBURN:** There is an installation under way on the Ohio River where rectifiers are going to be used in parallel with existing motor generator sets, furnishing power for a strip mill finishing train. They are going to use the motor generator sets on the Ward-Leonard and then use the rectifiers after the mill gets up to speed, and thus let the rectifier carry the straight line load, using the two motor generator sets to handle the variable voltage feature. But to date the manufacturers of rectifier equipment in the United States have not definitely come out and stated that they will guarantee a rectifier for variable voltage control. However, we still anticipate that this is coming. It is just a question of regulation and phase shifting, and a few minor details which have not been worked out yet.

**GEORGE GABOR:** What would the ripple in the pulsating wave look like if one of the tanks were kicked out by the breaker?

**L. R. MILBURN:** Every sixth one would be a miss, and there would be a jump and you could see a ripple in your lights. One thing I did not bring out. This rectifier as we use it today, whether it is a 6-tank or a 12-tank or one big tank with six or twelve electrodes, it is a full rectification the same as with any motor generator set.

**MEMBER:** What actually happens to the rectifier when it is kicked out?

**L. R. MILBURN:** Nothing, it is just out. There is no arc generated in there. There is no current that passes through that tank until you get the vacuum down again and get the tank firing, and then it will immediately pick up and come on to the line.

**MEMBER:** When the vacuum comes down and the arc is present, will it work properly again?

**L. R. MILBURN:** Yes, when the vacuum comes down and you get that tank firing again, it steps on the line and makes a complete 60 cycle rectification.

**GEORGE GABOR:** If it happened that two tanks kicked out of the circuit, would that make any difference in the magnet on a crane?

**L. R. MILBURN:** If two tanks went out, we would have to take the machine off the line until we could get them working again. It would cause the magnet to drop its load. However, we did run for approximately three days on five tanks.

When we ran the machine with one tank out of service, there were some disturbances noted on some of our sensitive under voltage devices, and this was our clue to the fact that something was wrong with the rectifier.

**GEORGE GABOR:** At the moment we will say that two tanks went out. Would it cause the magnet to drop its load before you could repair the damage?

**L. R. MILBURN:** Yes, the voltage would drop too low to hold the magnet load.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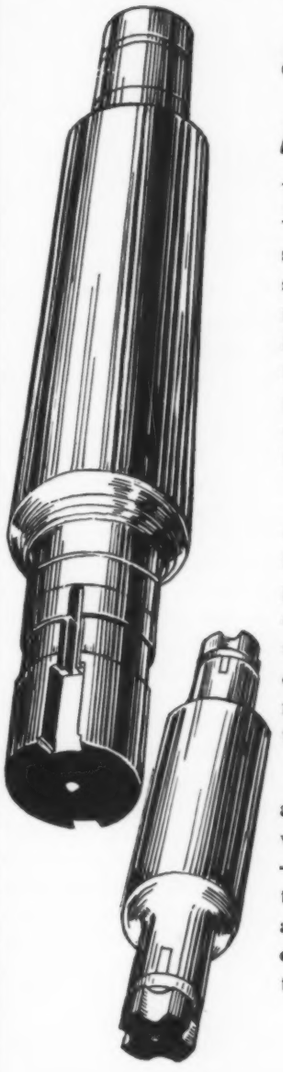

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# *Maintenance of*

# INSULATING OILS . . .

*By R. P. Dunmire*

VICE PRESIDENT

**Buckeye Laboraties**

CLEVELAND, OHIO

*. . . . this is the second article of a series devoted to the "Conservation of Oils Essential to the Steel Industry" . . . .*

Presented before A. I. S. E.
CLEVELAND AND YOUNGSTOWN DISTRICT SECTIONS

▲ UTILITIES and industrial organizations today have enormous sums of money invested in transformers, oil circuit breakers, regulators, capacitors, cables and other oil insulated electrical equipment. Much of this equipment also uses the oil as a cooling agent. It is essential that the insulating oil be kept in the best possible condition or increased maintenance cost, reduced life, electrical failures, expensive repairs and costly shut-downs of the equipment will result.

The emergency created by the present war makes it imperative that we conserve all the electrical power possible, as well as prevent the loss of many man-hours production time due to failure of essential electrical equipment of which transformers and circuit-breakers are most vital.

Many millions of kwhr are dissipated annually in iron and copper losses in transformers. Much of these losses can be eliminated by maintaining the oil in the best condition possible so as to insure the proper heat transfer and dissipation of the heat energy. Consequently, greater loads may be carried without overheating and many transformer failures avoided which cause the loss of invaluable production time.

Break-downs in dielectric strength of the oil and consequent loss of the transformer due to moisture and other foreign materials in the oil, can be easily avoided by careful maintenance. Maintenance of circuit breaker oil is also vital inasmuch as it would be impossible to protect motors, generators, transmission lines and transformers without the use of circuit breakers. The difficulty of securing replacement transformers may also be reduced due to decreased failures.

The expenditure of a very small percentage of the total investment is sufficient to keep the oil in the best possible condition and there can be no doubt that this expenditure is returned many times. Yet, many organizations hesitate or refuse to spend the slight increase in cost for equipment which will maintain the oil in the best possible condition, and permit the small saving in initial cost to influence the purchase of less adequate equipment. In the selection of the oil maintenance equipment consideration should extend beyond the value of the oil itself and include the effect of the condition of the oil on the life and operation of the expensive electrical equipment. In a great many cases a single electrical failure results in a loss in excess of the total cost of adequate equipment for maintaining the oil in the best possible condition.

Before discussing modern methods and treating systems for the maintenance of insulating oils, a general discussion is advisable. A review of insulating oil

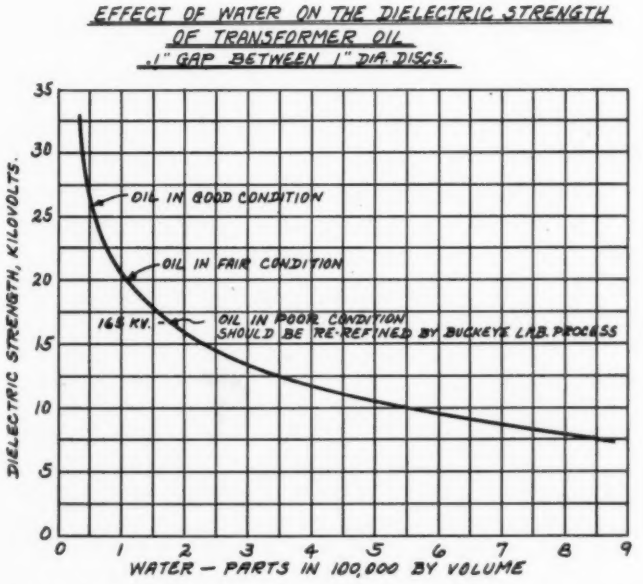



**Figure 1 — Curve showing effect of water on the dielectric strength of transformer oil.**

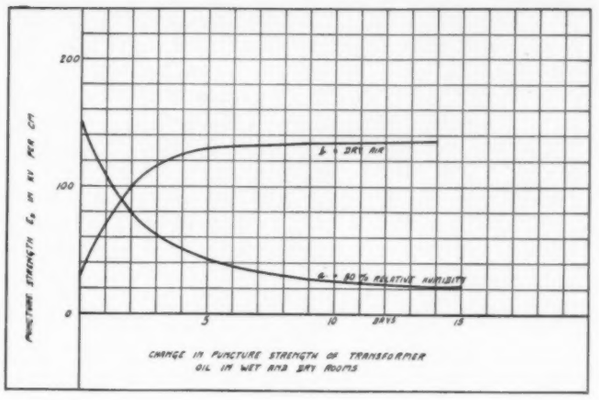



**Figure 2 — Curve showing effect of humidity on puncture strength of transformer oil.**

▲

**Figure 3 — Graphical presentation of the effect of air in contact with a fluid insulating material.**

characteristics including the effect of moisture and other contaminants follows. A specification for transformer insulating oil is also included.

### Electrical Insulating Oil

It must be realized in the treating of the subject of oils in high voltage apparatus the condition is such that we never have a clean oil, no matter how carefully the oil is processed and serviced before use. It is almost impossible to prevent it from taking up water and other impurities which cause a marked reduction in its puncture or breakdown value.

Comparatively little is definitely understood regarding the process of breakdown of a dirty oil. Shroter and Hoschsoule and Slepian made many observations along these lines. It has been found by microscopic observation that the process of breakdown in a dirty oil is such that the impurities formed in the oil bridges the space between the electrodes thus causing breakdown. It has been noted that as soon as voltage is applied to a pair of electrodes, all the particles in the region of the electrodes which have dielectric constants higher than the field, immediately begin to move into the field where they travel toward the electrodes and at the same time adhere to one another until the distance is wholly or partially bridged. In a strong field this occurs in a fraction of a second; in a weak field it occurs more slowly.

In general, the high dielectric content of the filament path through the oil is somewhat of a function of its water content. A partial bridging over the gap by such particles caused a reduction in breakdown voltage. Quite often moisture causes gas bubbles to rise. It has been shown experimentally that with increasing water content the dielectric strength of the oil decreases rapidly at first then more slowly, tending to reach a limit of about 20 kv per centimeter.

Schoter found that water-drops with a diameter of one micron permeated the oil fairly regularly. As soon as voltage was supplied to the gap, these particles entered into the gap from all parts of the field which caused a moisture contamination at the gap and caused breakdown.

It has been shown that the insulating strength of an oil is greatly decreased by its water content as illustrated by the curve Figure 1, as well as the affect of wet and dry rooms on puncture voltage, Figure 2.

The question which naturally arises is what means may be used to dehydrate the oil and what degree of dryness can be obtained. Recent developments have shown that a simple and practical method of vacuum treating and filtering of such oils has been developed and applied in the field for a period of ten years with definite results as to quality and the method is found to be economical. Full description of this method is contained herein.

Another question arises, i.e.: what is the actual breakdown voltage for clean oil? Koch has found that the insulation strength of oil, like that of air, increases materially with the increase of pressure. Prior to Koch's experiments, Gunther-Schulze set a theory for breakdown for fluids and assumed that the spark distance in oil is a "veiled gaseous discharge." In the field the ions are first accelerated and heated because of the friction of the oil particles entering their path. Secondary ionization takes place in the path causing neutral particles to be broken down and impact-ionization occurs in the vapor channel.

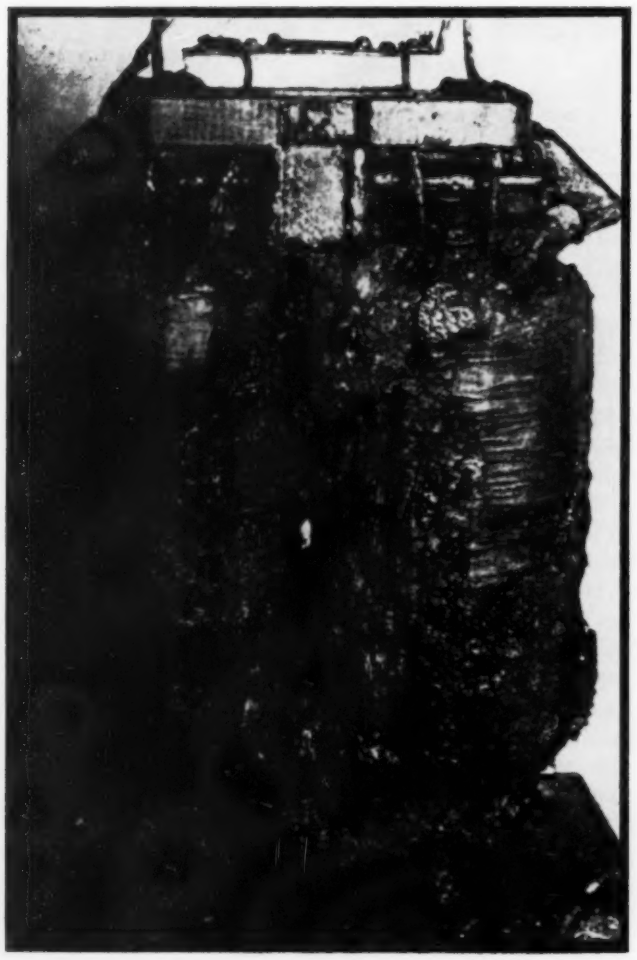
Gruger and Sorge found by testing oils under various conditions that the insulation strength of oil is not a constant of the material, but depends on the spacing, also upon the radius of curvature of the electrodes. It is to be noted that transformer oils as above mentioned under test show an increase rather than a decrease of dielectric strength without an increase of temperature which is accounted for by the viscosity of the oil. Therefore, the law governing this relation is unknown

and it is recommended that an oil should be tested at a temperature at which it is to be used mostly at from 70 to 80 C.

### Contamination of Insulating Oils

The application of organic liquids for insulation purposes depends primarily upon their stability against chemical changes, particularly oxidation. It is shown that primarily two conditions must be fulfilled in the molecular structure: (1) no oxygen in the original molecule; oxidation progresses at an accelerated rate after initial occurrence; and (2) absence of double bonds, because such bonds are readily broken and cause oxidation. The velocity of oxidation depends mainly upon the partial pressure of oxygen and upon temperature; it increases with both. Besides, three other causes may accelerate oxidation, namely, (a) admixtures of foreign substances particularly of metals with multiple valence which act as catalysts; (b) boundary surfaces which act as adsorption agents, thus accelerating oxidation partly by causing a greater concentration of reactive groups and partly by activating the atoms; and finally (c) electrolytic processes which cause unstable radicals to be positively charged at the anode and thus facilitate their combination with oxygen or hydroxyl ions.

**Figure 4 — Transformer in which insulating oil was converted into sludge after long operation under abnormal conditions.**



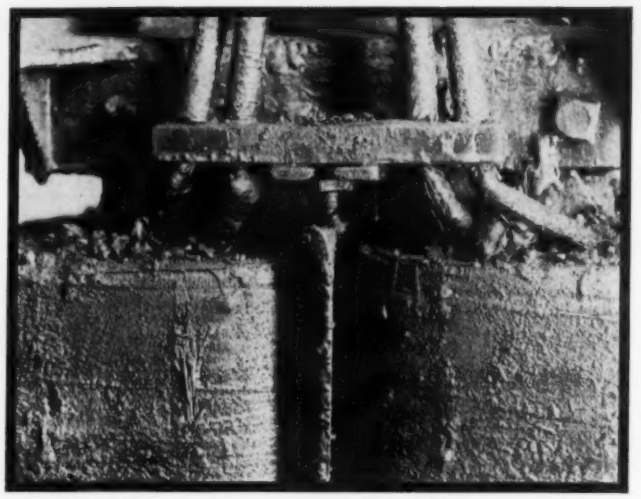


**Figure 5 — Sludge from poor transformer oil deposited upon active parts of small transformer. A small initial deposit accelerates further deposition.**

By studying Figure 3, which shows graphically the effect of air which contains water, vapor, oxygen, nitrogen, dust, etc., when brought into contact with a fluid insulating material under varying barometric pressure, temperature and phase many of the major causes of oil deterioration may be traced as well as the effects of the same.

Sludges of various forms and nature are the chief causes of the deterioration of such insulative media.

In a more pronounced form of oxidation a sludge gradually deposits upon the hottest parts of the core and windings of the transformer — this type of sludge seems to have little effect on lowering the dielectric strength of the oil, but if it becomes pronounced it interferes with the oil circulation and the dissipation of heat from the surfaces on which it forms. Analyses of this type of sludge show the presence of oxygen in abundance.

Sludges have always been found in the circulating system of even the best insulating oils — these sludges consist of water and solid impurities, but more especially of soap type and asphalt-like grimy substances formed by a reaction between oxygen and oil at the temperatures of operations. Some of the soap and asphalt-like substances are soluble in the warm oil, but settle out when the oil is cooled. For this reason they are found principally around the cooling coils, radiators and oil ducts. These sludges cement the other solid contaminents into a dense mass, which is a good heat insulating material, so that their precipitation in the cooling ducts and radiators results in higher operating temperatures.

The form of sludge called the "soap type" is produced by oxidation when acids liberated by slow decomposition of the oil come into contact with metals inside the case. This type of sludge has a great affinity for water and its presence has considerable effect upon lowering the dielectric strength of the oil. It is usually of a light brown color and is found in combination with some oxidized hydrocarbon residue containing a high percentage of moisture.

It has been found that the rate of formation of acids

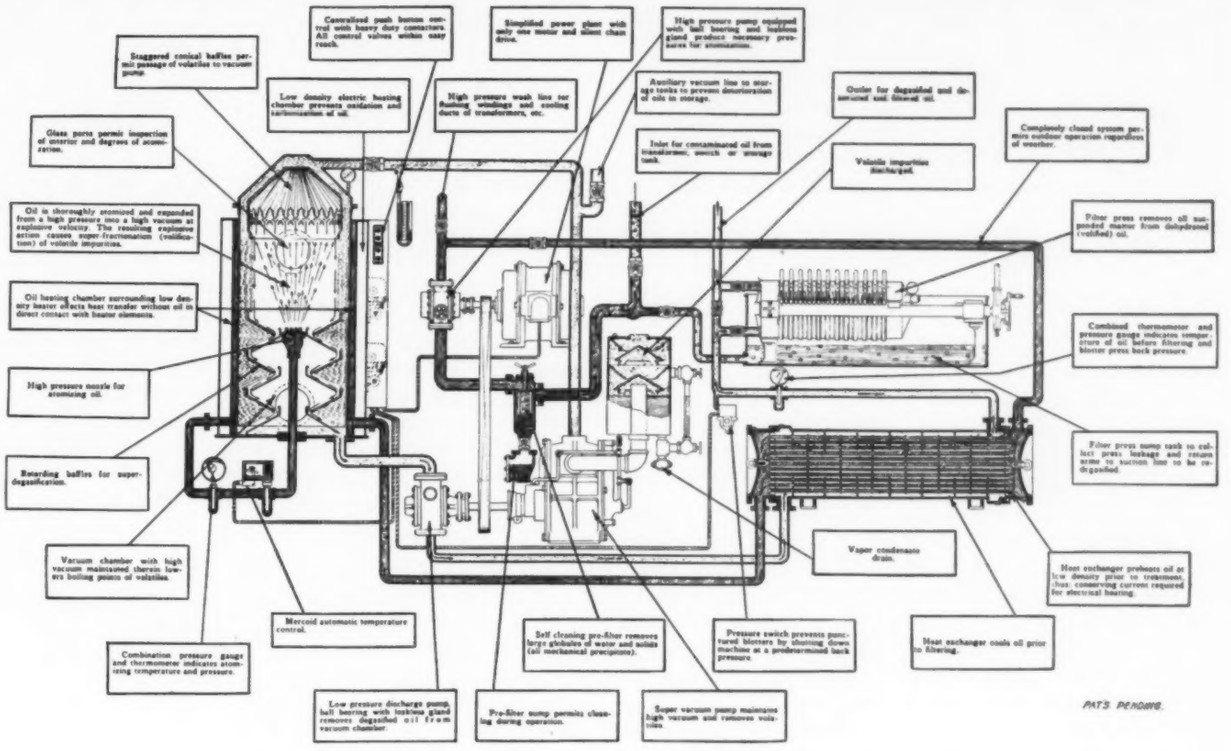

Staggered conical baffles permit passage of volatiles to vacuum pump.
Centralized push button control with heavy duty contactors. All control valves within easy reach.
Simplified power plant with only one motor and silent chain drive.
High pressure pump equipped with ball bearing and leakless gland produce necessary pressures for atomization.
Low density electric heating chamber prevents oxidation and carbonization of oil.
High pressure wash line for flushing windings and cooling ducts of transformers, etc.
Auxiliary vacuum line to storage tanks to prevent deterioration of oils in storage.
Outlet for degassed and dehydrated oil.
Glass ports permit inspection of interior and degrees of atomization.
Inlet for contaminated oil from transformer, switch or storage tank.
Volatile impurities discharged.
Completely closed system permits outdoor operation regardless of weather.
Oil is thoroughly atomized and expanded from a high pressure into a high vacuum at explosive velocity. The resulting explosive action causes super-fractionation (volatilization) of volatile impurities.
Filter press removes oil suspended matter from dehydrated (volatilized) oil.
Oil heating chamber surrounding low density heater effects heat transfer without oil in direct contact with heater elements.
Combined thermometer and pressure gauge indicates temperature of oil before filtering and blotter press back pressure.
High pressure nozzle for atomizing oil.
Filter press sump tank to collect press leakage and return same to suction line to be re-degassed.
Retarding baffles for super-degasification.
Vapor condensate drain.
Vacuum chamber with high vacuum maintained therein lowers boiling points of volatiles.
Heat exchanger preheats oil at low density prior to treatment, thus conserving current required for electrical heating.
Mercoid automatic temperature control.
Self cleaning pre-filter removes large globules of water and solids (all mechanical precipitate).
Pressure switch prevents punctured blotters by shutting down machine at a predetermined back pressure.
Heat exchanger cools oil prior to filtering.
Combination pressure gauge and thermometer indicates atomizing temperature and pressure.
Low pressure discharge pump, ball bearing with leakless gland removes degassified oil from vacuum chamber.
Pre-filter sump permits cleaning during operation.
Super vacuum pump maintains high vacuum and removes volatiles.
PAT'D. PENDING.

**Figure 6 — Schematic diagram showing operation of the hydrovolifier.**

and asphalt-like deposits doubles for about every 22 F rise in oil temperature, so that any temperature increase results in an even more rapid formation of additional sludge. Both the asphaltic and acidic sludges are strong emulsifying materials, and are, therefore, doubly objectionable.

During "breathing" of electrical apparatus, especially transformers, humid atmosphere in contact with metal and oil surfaces, condenses small quantities of moisture, which may be taken up readily by impure oil. The better refined oils do not hold $H_2O$ in suspension, but allow it to settle to the bottom of the tank where a quantity of $H_2O$ may accumulate without breakdown.

If any soap sludge is present, the moisture content of the oil is raised. Dust particles, minute asphaltic bodies, and any form of suspended matter in the oil tend to act as moisture carriers through absorption or by means of nuclear condensation.

Particles capable of being charged, especially in the electrical field of the transformer or other apparatus act as carriers of oxygen and moisture, which are two of the most undesirable impurities in oil.

Certain organic acids high in oxygen, as $C_{12}H_{22}O_2$ as well as fatty acids of the general formulae, $C_nH_{2n}+_1COOH$ or $C_nH_{2n}O_2$ are derivatives of the hydrocarbon oils and may be formed under favorable oxidizing conditions. They react slowly with metals and oxides to form soaps. Unprotected copper greatly accelerates sludge formation.

## Carbon Type of Sludge

A third type of sludge which is distinctly characteristic of electrical breakdown may be present in transformer oil. Corona discharge or any arcing within the oil breaks down the oil to amorphous carbon, saturated and unsaturated members lower in the series, and to various gases consisting mostly of $H_2$ (60 per cent), unsaturated gases (20 per cent and $CH_4$, CO, $CO_2$, $N_2$. High voltage and low current discharge gives a very finely divided carbon of a semi-colloidal nature, whereas low voltage and high current produces comparatively large particles of carbon sludge. The finely divided sludge or precipitate is nearly pure amorphous carbon having a high specific resistance. The coarser precipitate contains much free carbon with small amounts of hydrocarbons low in hydrogen. Its specific resistance is lower than that of amorphous carbon. No graphite carbon is found as a result of electrical breakdown within the oil. However, if an arc plays near the surface of the oil where atmospheric oxygen is present "graphitoidal" carbon is formed. These forms of carbon are more conducting than amorphous carbon and graphitic carbons. Some forms of carbon sludge contain oxygen in small proportions, suggesting an acidic character.

Sludging of the oil, accumulation of deposit, the development of hot spots and the consequent weakening of the insulation have been the cause of many trans-

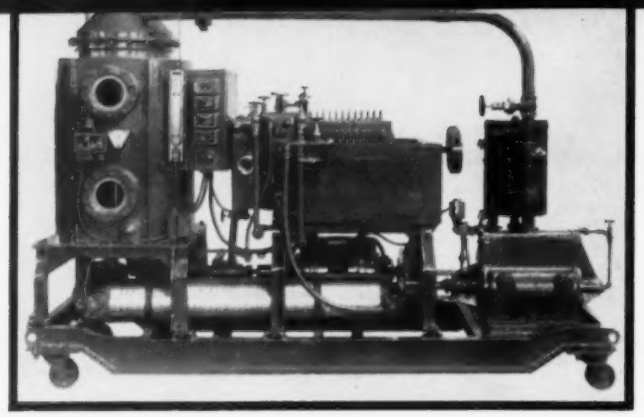


**Figure 7 — Hydrovolifier of portable type, 600 gal per hr capacity, for purifying insulating oils.**

former failures. A good example of such conditions is illustrated by Figures 4 and 5.

### Effects of Gases in Transformer Oils

Gases play a very important role in transformer practice, and as shown above, an oxidizing condition brought about by air has a harmful effect. This effect is greatly influenced by oxygen concentration, by temperature rise and by the presence of catalysts.

Transformer oil of standard quality can be turned completely into sludge, the rate depending on the supply of oxygen and temperature of the transformer. Some oils sludge more rapidly at first, the rate diminishing with the decrease of available oxidizable constituents. This is particularly true where low operating temperatures are used.

On the other hand, a similar oil also in contact with atmospheric air, but operated at excessive temperatures may have a rate of sludging increasing with time.

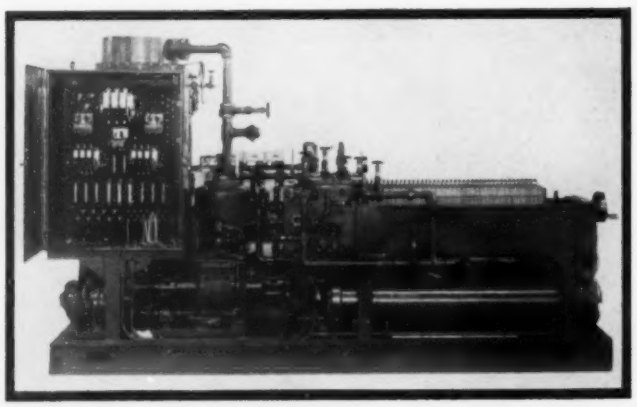
Thus, it is seen that oxygen is closely associated directly or indirectly with the formation of sludges and other undesirable constituents in insulating oils. Some of these undesirable constituents are unsaturated hydrocarbons, alcohols, aldehydes, ketones, fatty acids, napthenic acids, residue carbons, esters, oxasphaltic compounds, varnishes, soaps and water. It has been demonstrated that the vacuum treatment of insulating oils can be accomplished in the field in a very economical manner, thus, improving the operation and maintenance over other methods of purification.

Other gases such as those from electrically decomposed oils due to abnormal operation of transformers, the normal operation of circuit breakers, and sudden abnormal electrical surges, may result in the deterioration of insulation and cause subsequent failure and electrical breakdown. Whatever the cause of the failure of the apparatus, it has been shown that certain gases, decomposition products of insulation or oil, all are the result of electrical discharge. Since the insulation media are chiefly hydrocarbons, and since the intense heat and pressure of electrical discharge cause sudden rupture of the material, it seems probable that the products formed are largely elements.

This supposition has been confirmed experimentally. Finely divided amorphous carbon having a density of 1.82 hydrogen and some hydrocarbons lower in molecular weight are found. Nearly 70 per cent of the volume of gas formed is hydrogen; the remainder consists of 2 to 3 per cent methane, and some unsaturated gases of the acetylenes and olefines. The combustible gases when mixed with air contained in the gas space above the oil in the transformer may be easily ignited, causing an explosion, the force of which depends on the composition of the gas mixture.

Equipment to accomplish the purification of liquid dielectric has been designed and has been in operation over a period of time sufficient to prove its efficiency, and will remove contaminants such as free and dissolved $H_2O$, light volatile unsaturates, gases, solids such as carbon and other materials of like nature. Such apparatus is known as the hydrovolifier and operates in line with well recognized physical laws. This will be discussed further.

**Figure 8 — Stationary type of hydrovolifier, 1200 gal per hr capacity, for insulating oil purification.**



### Routine Testing of Oils

Too much emphasis cannot be placed on the importance of regular inspection and testing of insulating oils both in service and in storage. Too much care cannot be used in the sampling and testing. It is strongly recommended that the Edison Electric Institute recommendations for the storage, handling, inspecting and testing of oils be strictly adhered to. Routine tests should be made semi-annually for acidity, neutralization number, dielectric value, etc.

### Specifications for Transformer Insulating Oil

(Requirements and Testing)

1. *General* — These specifications cover oil to be especially selected for use with electrical devices immersed in oil for the purpose of insulating and cooling. These specifications do not cover oil for use in cables and cable end bells.

The insulating oil shall be the pure mineral oil obtained by fractional distillation of petroleum. It shall not contain moisture, acids, alkalis, free sulphur or any other substances which will affect its insulating and cooling qualities, and shall be of a quality which will not affect adversely or be affected adversely by the insulation, the insulation varnish or other parts of the equipment with which it will be used.

2. *Flash point* — The flash point shall not be less than

130 C as determined by test Methods D-92-24 A. S. T. M. Standards, 1930, Part II, page 517.

3. *Fire point* — The fire point shall be not less than 140 C as determined by Test Method D-92-24, A. S. T. M. Standards, 1930, Part II, page 517.

4. *Pour point* — The pour point shall be not higher than minus 40 C as determined by Test Method D-97-30, A. S. T. M. Standards, 1930, Part III, page 481.

5. *Viscosity* — The viscosity shall be not less than 52 seconds Saybolt at 37.8 C nor greater than 70 seconds Saybolt at 37.8 C as determined by Test Method D-88-30, A. S. T. M. Standards, 1930, Part III, page 550.

6. *Neutralization number* — There shall be required not more than 0.05 milligrams of potassium hydroxide to neutralize 1 gram of the oil as determined by Test Method D-186-27-T, A. S. T. M. Tentative Standards, 1930, page 378.

7. *Mineral acids (chlorides and sulphates)* — The oil shall show the absence of mineral acids (chlorides and sulphates) as determined by Test Method D-117-27, A. S. T. M. Standards, 1930, Part II, page 1008.

8. *Free and corrosive sulphur* — The oil shall not contain free sulphur or corrosive sulphur compounds as determined by Test Method D-117-27, A. S. T. M. Standards, 1930, Part II, page 1008.

9. Sludge — No visible sludge deposit shall appear in less than 18 days continuously under the Snyder Life Test as published in Appendix to Report of Committee D-9, 1927 Proceedings, A. S. T. M. Standards, Part I, page 541.

10. *Steam emulsion test* — The steam emulsion number of the oil shall not exceed 25 seconds as determined by Test Method D-157-28, A. S. T. M. Standards, 1930 Part II, page 537.

11. *Dielectric strength* — The dielectric strength of the oil shall not be less than 25 kv as determined by Test Method D-117-27, A. S. T. M. Standards, 1930, Part II, page 1009.

12. *Sampling methods* — The oil sampling procedure for these tests shall conform to the methods outlined in D-117-27, A. S. T. M. Standards, 1930, Part II, page 1004.

13. *Color* — Color of Oil — No. 1, A. S. T. M.

14. *Power factor* — Indicated power factor or dissipation factor may be tested for with a modified Scheering bridge. Definite specifications, maximum and minimum power factor value are being prepared by the Edison Electric Institute.

### The Hydrovolifier Process

Heretofore, it has been attempted to remove water suspensions by gravity, by centrifugal force and by filtration. These processes, however, have been only partially successful because they failed to remove water of true solution, volatile hydrocarbons and dissolved oxygen.

The phenomena of boiling includes the overcoming of atmospheric pressure by the vapor pressure of the substance being treated. The vapor pressure of most petroleum products does not approach atmospheric pressure until there has been a very considerable rise in temperature. Therefore, if the atmospheric pressure is removed, the boiling occurs at a much lower temperature which happens to be the principal which underlies the process of distillation; for example; an oil having a boiling point of 400 F at atmospheric pressure will have a boiling point of 225 F at 10 millimeters pressure. The decrease in boiling point for a slight decrease in pressure is quite marked especially after high vacuums have been obtained.

In a vacuum of 29.74 in. referred to 30 in. vacuum at sea level, the boiling point of $H_2O$ is 34 F. Inasmuch as the low density heated liquid is processed at about 140 F, any water of solution and highly volatile compounds will assist to break up a finely atomized liquid with explosive disruption under the instantaneous high to very low pressure shock drop. No appreciable frothing is possible under this disruptive action.

The water and lighter hydrocarbons are immediately converted into gases or vapor which is in a more or less super-heated state. Thus super-fractionation is carried on at a very high speed and is controlled by the flexible factors of pressure, temperature and design of equipment.

The hydrovolifier does accomplish the above in a purely physical manner without any chemical treatment, the method being both logical and simple — the device being in effect a complete low temperature vacuum distillation process in portable form and so simple that no experience is necessary to produce the super-purification of insulating oils.

By referring to the flow diagram, Figure 6, the passage of the oil may be readily traced through the various steps of the process, viz:

The intake line delivers oil to the primary filter, which is cleaned while in use by a simple turn of the handle and an occasional draining of the sump. The purpose of the primary filter is to remove all particles of lint, metals, heavy sludge, heavy amorphous carbon and a large portion of the free water. The oil then passes into a suitable pump which raises the pressure. The pump is fitted with a by-pass valve, so that the pressure is automatically maintained and no further adjustments are required.

The oil is then conducted through a heat exchanger, of a multi pass high efficiency type. This arrangement makes possible the heating of the oil with fifty per cent or less of the electrical energy that would normally be required, and in addition there is no risk of injuring the oil. Conversely, the heat exchanger also functions to cool the hot oil before filtering and provides against tank sweating by discharging the oil at near tank temperatures.

The oil from the heat exchanger is conducted to a special low density heater of the oven type which surrounds the vacuum chamber and insures the heating of the oil to the proper purification temperature without oxidation or causing injury due to overheating. The importance of low density heating of oils is paramount. Many complex factors enter into the problem of heating oil due to the variation in the chemical characteristics of different oils and to their temperature and physical condition. The viscosity of the oil, its heat conductivity, specific gravity, velocity and pressure under which it is circulated over the heating surfaces, also the design and shape of the passages which conduct the oil over the heating surfaces, the physical condition of the oil as to its air and water content, and its critical temperature,

or that at which it will begin to deposit carbon, have all to be taken into consideration.

The above problems have been satisfactorily solved and applied to the hydrovolifier in the following manner; the vacuum tank is designed with a double wall, the inner one forming a closure for the vacuum chamber, and the space between the inner and outer wall providing the path for the oil circulation. This is divided into passageways so that the oil is forced through a prescribed circuit. The walls of the passageway through which the oil is pumped are heat electrically and transmit heat from their surfaces to the oil as it flows over them; the direction of the oil flow is changed at short intervals to give the proper turbulence to insure correct mixing and to break up the surface traveling along the walls.

The entire outside of the heated oil passage is thoroughly insulated against heat losses. The heating units are controlled by a temperature regulator which in turn operates heavy duty contactor switches interlocked with a manual control of three steps or degrees of temperature regulation thus avoiding the danger of injuring the oils. A temperature and pressure indicating instrument shows conditions of the oil at the atomizing nozzles.

After being heated the oil is introduced through atomizing nozzles in the form of interlaced cones of very fine mist projected at an extremely high velocity, into the vacuum chamber, thus subjecting the oil to a high low pressure differential shock. Removal of all injurious volatile contaminants (relatively high vapor pressure impurities) is suddenly and completely affected.

The vacuum chamber is equipped with two sets of baffles; the top conical baffle is arranged to permit the passage of the volatile gases to the vacuum pump, but collects the infinitely small particles of oil which have given up their volatile constituents. This action is accomplished by trough shaped baffles in conical form. The gases with entrained oil particles are directed toward the conical baffle at a high velocity and are divided into separate streams which pass through the baffle. During passage they are subjected to the action of centrifugal force several times, which throws the oil particles onto the baffle surface where they collect and are drained downward onto the lower baffles; the volatiles passing on through to the vacuum pump from whence they are discharged directly to the atmosphere. The nozzles are protected by the primary filter and do not need any adjustment or cleaning.

A mercury column is provided for reading the pressure within the vacuum chamber, and pyrex glass ports through which the conditions therein can be observed. The oil from which the light volatiles have been removed collects in the vacuum chamber, from which it is pumped through the heat exchanger to the blotter filter press for the removal of the solid impurities in suspension.

It is to be noted that the oil is now free of practically all moisture, both free and in solution. This insures the greatest ease and speed of filtration of all suspended matter. The efficiency of the filter medium is not impaired by the collecting of dry (water free) matter, the pressure builds up slowly and the blotters are changed frequently.

If the water were not completely removed, as in other processes the blotter filter back pressure would build up rapidly, necessitating frequent and expensive changes of blotter papers. The oil is then discharged direct from the filter press to the storage tank or into the apparatus from which the oil is being circulated.

Another feature tending to facilitate operation has been added in the form of a pressure operated switch which is interlocked with the heater control and motor control systems so that no attention need be given filter press back pressure or blotter condition. This switch functions to completely shut down the operation of the entire machine when the blotter press back pressure reaches a predetermined amount, thus eliminating the breakage of blotters due to over pressure and preventing any discharge of dirty oil into the apparatus.

A new type of press with vacuum treated blotter paper impregnated with dry oil is used which insures that the oil remains dehydrated. Figure 7 shows a 600 gallon per hour hydrovolifier, while Figure 8 shows a 1200 gallon per hour unit.

This development is a distinct advance in the art of conserving oils. The reconditioning is done free from contact with air. One pass is sufficient for complete reconditioning and the rated capacity is the actual production capacity. From used dirty oils the unit removes water-free and in solution, light fractions, gases and air, and dirt, scale and carbon.

Insulating oils purified in this manner are the best protection against failure in service. The freedom from impurities insures maximum continuity of use of the oil without reconditioning. The purified oil resists deterioration longer, maintains higher insulating value and better heat conducting properties. The metal surfaces tend to remain clean. Tests show that the average increase in dielectric value obtained by this process is far greater than obtained by other and more costly methods.

On a recent test conducted by one of the major utilities, a unit rated at 1200 gallons per hour purified oil containing one quart of water and in addition, 4 ounces of carbon black per 100 gallons at the rate of 1620 gallons per hour and raised the dielectric breakdown value from 0-10 kv to 35-40 kv, without a noticeable increase in back pressure on the blotter filter press, thus indicating definitely that all moisture was thoroughly removed by vacuum treatment prior to filtering. Exceptionally long life of the blotters was evident and a higher degree of filtration was obtained due to the anhydrous solids acting as a precoat material on the blotters.

In addition to the purification of insulating oil the hydrovolifier may be used for such purposes as vacuum drying of transformer and other electrical equipment; vacuum storage of oil pending use, thus preventing the deterioration of oil in storage tanks; upon being reconditioned, oils may be conveniently impregnated with inert gas and returned to service or storage, thereby preserving high quality of insulating oils indefinitely (oil from nitrogen-filled transformers can be dehydrated and degasified and then resaturated with nitrogen and returned to the transformer, in a fully saturated state); and vacuum filling of transformers and other equipment (this is important in impulse testing).

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# *Special Applications of*

# STEEL PLANT CONTROL

*By H. H. Angel*

ELECTRICAL DEPARTMENT

**Bethlehem Steel Company**

SPARROWS POINT, MARYLAND

*. . . . outlining several special applications of electrical control worked out for steel plant installations . . . .*

Presented before
A. I. S. E. PHILADELPHIA DISTRICT SECTION

▲ MANY problems are encountered in maintaining successful operation of the electrical equipment in steel mills, and adaptation of special controls is occasionally necessary to aid in their solution. During the past years, the writer has assisted in working out many such applications in the Sparrows Point plant of Bethlehem Steel Company; a few of these will be described in the following.

### Plate Mill Charging Crane Screw Control

The 10 ton charging crane is probably the most important crane in this mill. It is used in placing the hot slabs into the reheating furnaces and in removing them when the correct rolling temperature has been attained. This crane, as shown in Figure 1, consists of a bridge, trolley, rotating cab, hoist and the ever important screw. The function of the screw drive is to pick the slab off the charging buggy by gripping it between the end on the peel forging and the cross head on the moving screw. When the ends of the peel and cross head are in good condition, and properly tapered, an experienced operator has generally very little difficulty in handling the slabs. The operator shuts off the motor, when sufficient pressure has been exerted, to hold the slab between the peel and cross head.

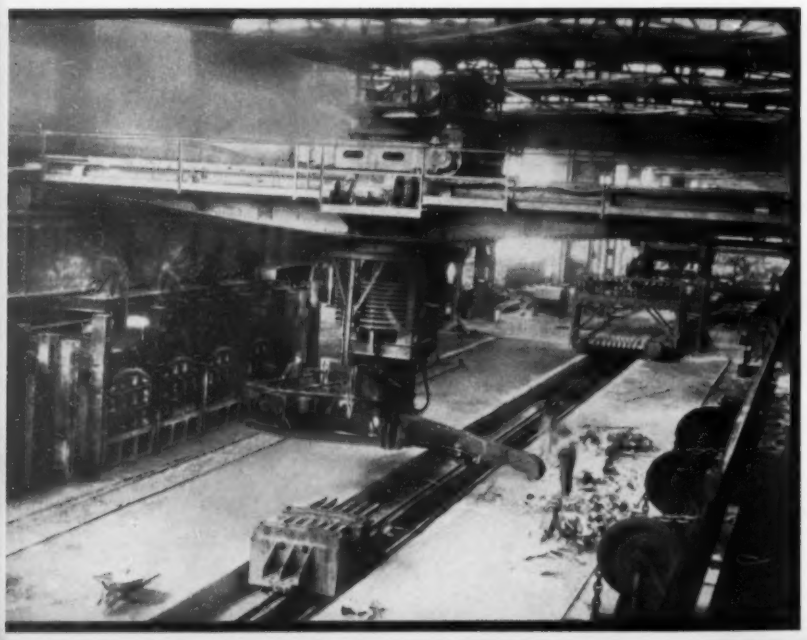
Failure to properly handle the controller results in stalling of the motor, setting up terrific strains in the screw mechanism. Occasionally, a slab is dropped on the ground and difficulty is sometimes encountered in the handling. Under these conditions, the peel and cross head will heat up more than usual, and if they are not cooled, the tapered ends become rounded. It will then be increasingly difficult to handle the slabs, and the operator may find it necessary to keep the power on for a longer time to hold them.

The screw drive was originally provided with slip gears, but the slippage encountered under the above conditions often prevented successful operation. The springs were tightened so much that the slip gear became ineffective. This placed the full burden on the motor and screw, resulting in frequent failures of these. A green operator, that is, a man with less than three months' experience, can damage this equipment in a very short time.

Jamming relays, using one series coil in the armature circuit, were tried on some cranes a number of years ago, but were not successful. The overheating of the armatures made it necessary to install blowers. This was of some help, but not sufficient, considering the maintenance necessary to keep a small direct current motor operating under the prevailing bad conditions.

Figure 2 shows an elementary diagram of control applied three or four years ago. The power circuit includes three accelerating contactors, the directional contactors,

**Figure 1 — Ten-ton plate mill charging crane, composed of a bridge, trolley, rotating cab, hoist and screw.**



a permanent resistor in the closing circuit only, and the series coil of the jamming relay. The elementary control diagram includes a shunt holding coil for the above relay and a time delay opening relay TSR. When the slab is jammed between the jaws and the motor current reaches approximately 250 per cent of full load, the relay armature pulls in to open contactor 3A, thus limiting the stalled current to approximately 150 per cent. The closing of JR energized the shunt holding coil to keep the relay closed when the armature current was reduced. Telegraphing would often occur without this feature. Should the operator leave the controller on while rotating or bridging, relay TSR drops out in about 5 seconds to open the closing contactors 1C and 2C.

The above has successfully reduced the armature and screw failures during the past three years. In 1937, approximately one armature failure occurred per 10,000 tons of steel rolled. During the years following the tonnage between failures has increased to between 20,000 and 37,500. Crane delays have also been considerably reduced.

The writer wishes to point out the slow-down resistance shunting the armature, which reduces the motor speed while moving the screw. The ohmic values of the shunting, permanent and jamming resistors are set at some compromise value to produce good operation. When first placed in operation, the permanent resistor was used in both directions, but occasionally a screw jammed pretty hard and not enough torque was available to move the screw outward. Likewise, it was necessary to have JR series coil in the closing circuit only, to avoid opening 3A under the above conditions. This control is not a cure-all. It is necessary to keep the mechanical equipment in the best possible condition and also to check the proper operation of the relays, resistors, etc., at least every 8 hours.

### Load Division Between Generators

In order to obtain more generating capacity for the increased size of the 600 volt motors driving the mill described, when it was speeded up in the latter part of December 1939, it was necessary to parallel the two existing 1,250 kw, 600 volt generators, of manufacturer "A," with a 2,300 kw, 600 volt generator, of manufacturer "B," which was moved from a different part of the plant. One of the prerequisites of the above is to have all machines with drooping voltage characteristics. The saturation curves of the generators were studied, and since the 2,300 kw generator was not as highly saturated as the 1,250 kw units, it was decided to use new shunt fields for the former, with provisions to adjust the shunting of the series fields of all generators.

When the mill was placed in operation, the 1,250 kw generators took more than their share of the load, up to about 450 volts, above which voltage the 2,300 kw generator carried the major load. Adjustments were made to the differential series field shunts, but the desired changes were not effected. The manufacturer of the 2,300 kw generator then suggested, in an attempt to possibly avoid the more laborious method of slotting the main poles, that the shims under the pole pieces be slotted. This was intended to give the saturation curve a more decided knee, in order to approach that of the two 1,250 kw units. The shims were removed, slotted and the air gap was reduced slightly, but the results were not as good as expected.

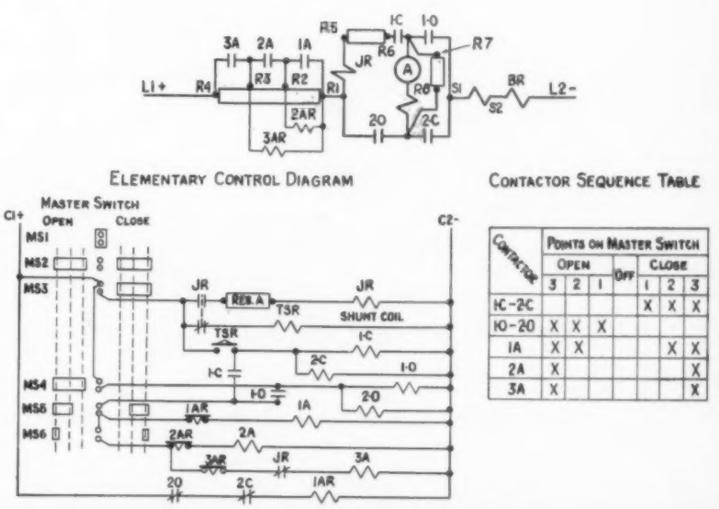
In order to improve the load division, the changes shown in Figure 3 were made in the generator field control. The output leads of the exciter are connected across the fields of generators 1, 2 and 3, with suitable resistors in series. The field of No. 3, which is the 2,300 kw unit, has a permanent resistor in series and also in parallel. Nos. 1 and 2 have independent series resistors and a common permanent resistor. Contactor F01 is used to transfer the fields of generators 1 and 2 to a different source of power, when applying these generators to start up a 20,000 kw frequency changer. In order to obtain better load division, relays GF3 and GF4 were installed to cut out the permanent resistance. These were controlled by voltage relays connected across the bus. When the bus voltage reached 150, relay GF3 opened, and at 450, GF4 opened. This aided considerably in load distribution.

Since the inductance of the 2,300 kw generator is less than that of the 1,250 kw units, the field flux decays faster, resulting in reverse current as the voltage is lowered to decelerate the mill. To correct this condition, a permanent resistance of 40 ohms was connected across the field. This was insufficient, and a Down-1 relay was installed to connect an additional 10 ohms across the field, as well as to short circuit the permanent resistance. The coil of Down-1 relay is connected in parallel with the coil of the relay controlling the lowering direction of the motor-operated field rheostat. These relays have improved the operation and there is no reverse current during normal stopping. In emergency stopping, ES-1 relay opens to prevent short circuiting the permanent resistance. This feature prevents the collapse of the 2,300 kw generator field more quickly than that of the other fields, because the field of the exciter is opened to produce emergency stopping.

The next step was the slotting of the generator pole pieces. A slot 5½ in. wide by 1 in. deep was milled in each pole piece, with the center of the slot corresponding to the line through the centers of the two bolts holding the pole pieces in position. Means were also provided for holding shims in these slots.

Table I is a tabulation of field currents and voltages of the generators, four ⅛ in. x 5 in. steel shims being

**Figure 2 — Elementary power diagram of plate mill charging crane screw control.**




CONTACTOR SEQUENCE TABLE

| CONTACTOR | POINTS ON MASTER SWITCH | | | | | | |
|---|---|---|---|---|---|---|---|
| | OPEN | | | OFF | CLOSE | | |
| | 3 | 2 | 1 | | 1 | 2 | 3 |
| 1C-2C | | | | | X | X | X |
| 1O-2O | X | X | X | | | | |
| 1A | X | X | | | | X | X |
| 2A | X | | | | | | X |
| 3A | X | | | | | | X |

**TABLE I — No. 1 Cold Tandem Reducing Mill**
**Field Current-Voltage Data of 600 Volt Generators**

| 2300 kw generator | | 2–1250 kw generators | | |
|---|---|---|---|---|
| Line volts | Field amps | Line volts Av. of 2 gen. | Field amps sum of both | Per cent of 600 volt field amps |
| 105 | 2.50 | 100 | 5.00 | 13.7 |
| 213 | 5.30 | 205 | 9.70 | 29.1 |
| 292 | 7.25 | 287 | 13.55 | 39.7 |
| 305 | 7.75 | 298 | 14.25 | 42.6 |
| 403 | 10.60 | 401 | 21.40 | 58.2 |
| 495 | 13.75 | 500 | 26.25 | 75.5 |
| 507 | 14.20 | 512 | 26.60 | 77.8 |
| 567 | 16.70 | 569 | 31.30 | 91.8 |
| 613 | 19.00 | 613 | 35.00 | 104.4 |

used in the pole piece slots. Much improvement was noticed in the division of the load. Relays GF3 and GF4 were eliminated but it was still necessary to maintain the two sets of field discharge resistors and the relays to cut out the permanent resistance during deceleration. The knife switch paralleling Down-1 contactor was installed to allow the 2,300 kw generator to take more of its share of the load during the first four or five hours of operation of the starting-up turn after the week end shut-down. The practice is to roll coils imposing the greatest load on the mill at the beginning of the week's operations.

### Auxiliary Drives in Skelp Mill

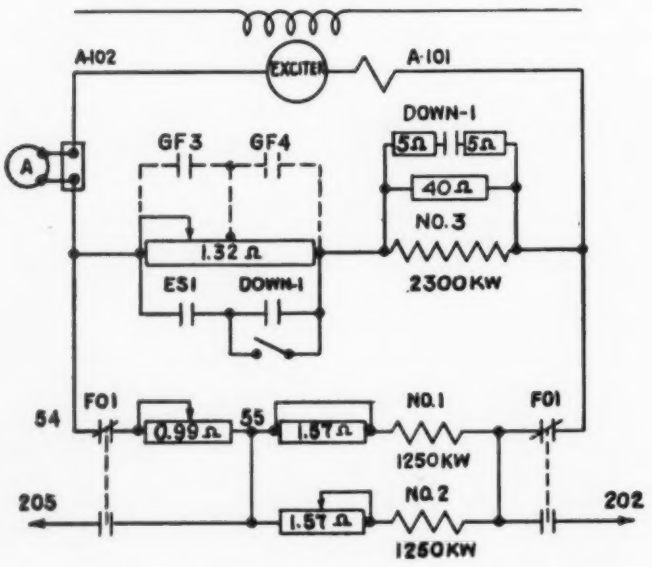
The strip reel consists of a horizontal platen having a few vertical guides around which the strip, moving on edge, is wound into a coil. A 3-to-1 adjustable-speed motor is used for this application. The control as originally purchased consisted of a non-reversing panel containing three accelerating contactors, three dynamic braking contactors and a large hand-operated face plate type combination master switch and field rheostat with 88 speed points. To start the reel, the rheostat lever was pushed forward four points to close the accelerating contactors. Continued forward movement inserted resistance in the field circuit to obtain the desired speed. Moving the lever to the "off" position decelerated the motor and then removed power. Further backward movement provided control for three dynamic braking contactors.

This type of controller gave excellent speed control but was inconvenient to operate and occupied a good deal of valuable space. Consideration was given to motorizing this master controller, but it was thought that the high speed necessary for such movement would require a slow-down and involve complications. In spite of the fact that smooth field weakening might not be obtained, it was decided to try some standard type of master switch having five points forward, an "off" position point and two points dynamic braking. The first point forward controlled the line contactors, and the second point the three automatic accelerating steps. The third, fourth and fifth points controlled three field-weakening, time-delay opened relays. The first dynamic braking point controlled one of the dynamic braking contactors, and the second point the remaining two. The counter emf relay control of the last two dynamic braking contactors, as originally furnished, was unchanged. After this control had operated for about a week, the results were considered so satisfactory that equipment was made up to change over the second strip reel.

The vertical guides around which the strip is coiled are moved up and down by a lowering center drive. A strip reel push-off pushes the coil off the platen onto a coil conveyor. This coil conveyor in turn moves the coil away from the end of the push-off mechanism through a distance of one cycle, equivalent to the diameter of the largest coil rolled. This equipment was interlocked electrically through counter emf relays and geared limit switches, so that no motions could be operated if the strip coiling reel were running. It was also impossible to operate the reel unless the vertically moving lowering center was in the raised position, the push-off in the back position, and the coil conveyor in the initial position. Likewise the coil could not be pushed off the platen unless the lowering center was down. After the coil was removed, the push-off had to be in the back position before the lowering center was allowed to raise

Separate masters were originally furnished for independent control, with provision to operate the lowering center and push-off automatically with one master switch. This was satisfactory, but it was considered more convenient to have the movement of one master switch operate the lowering center, the push-off and the conveyor automatically. After the coil is wound the operator moves one master. The lowering center lowers, stops, and then starts the push-off through one complete cycle. At the end of this cycle the lowering center raises, to be in position for an oncoming coil, while the coil conveyor moves the coil a distance of one cycle. It is also possible, by means of a throw-over master switch near the operator, to operate the coil conveyor with another master switch at a location in the cooling yard at the end of the conveyor. This necessitates additional interlocking of master switches, making the installation quite complicated. However, satisfactory results are being obtained.

**Figure 3 — Diagram of field circuits of three generators on tandem cold reduction mill.**



# IR DROP *Compensation on* CLEANING LINES

*By J. Raymond Erbe*

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*. . . . a method for accurate synchronization of the speeds of the various motor drives in a strip cleaning line . . . .*

Presented before A. I. S. E.
PHILADELPHIA DISTRICT SECTION

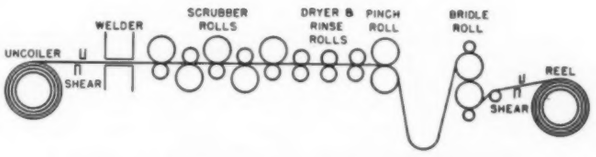
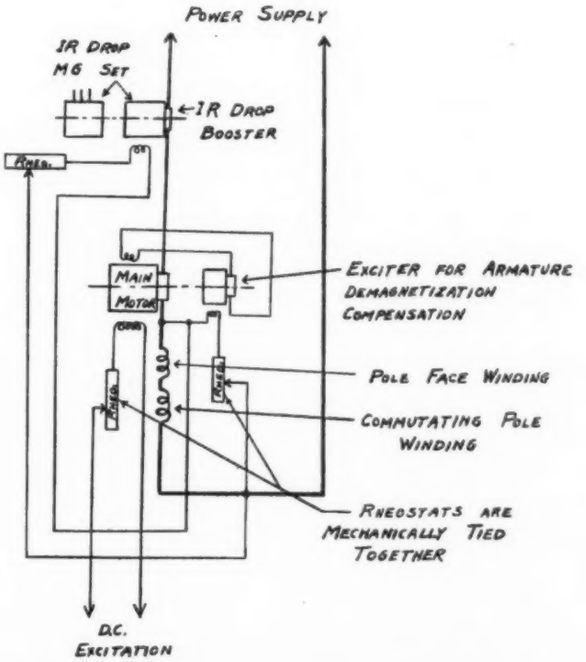



**Figure 1 — Schematic layout of cleaning line.**

▲

**Figure 2 — Demagnetization and IR drop compensation for d-c adjustable speed motor.**




▲ THE past decade has seen great improvements being made in the production of flat rolled products. Each year has seen the addition of new continuous cold rolling mills capacity for the production of sheets and tinplate.

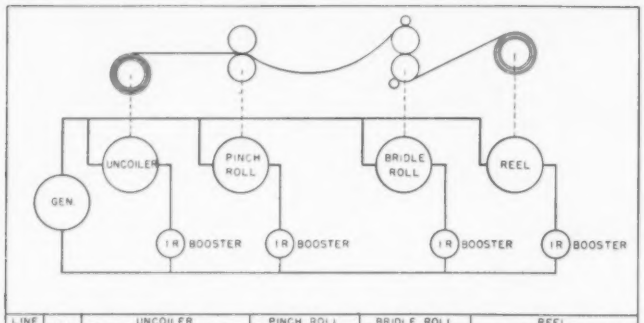
Each new installation has seen new developments included, to not only improve the quality of the product but to produce it, at a higher speed. The delivery speed of continuous cold rolling mills has increased from a maximum of 360 fpm in 1928 to 3500 fpm this year.

The development of the continuous hot and cold strip mills has created a need for new method of preparing the steel for cold and temper rolling in the mills and in shearing, trimming, slitting and applying coating after rolling to meet any given specification. The various machines used for any of these processes are mounted in tandem so that the steel travels from one machine to the next and the combination of the machines has become known as a continuous processing line. Some of these lines were unknown before the development of the continuous hot and cold strip mills and others have been changed and improved to meet the new conditions.

The subject of processing lines is very broad and covers at least five principal operations.

In this paper, we will limit the discussion to a consideration of cleaning lines. The function of this type of line is to remove the oil that is used in the cold rolling process. The development and delivery speed of these lines has approximately paralleled that of the continuous cold rolling mills. There is a cleaning line now operating at approximately 2,500 fpm.

Without any further introduction let us consider what constitutes a cleaning line and some of the problems which have been encountered in its development. Referring to Figure 1, we see that a cleaning line essen-




| LINE SPEED FPM | GEN. VOLTS | UNCOILER | | | | PINCH ROLL | | | BRIDLE ROLL | | | REEL | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | IR DROP | CEMF | 60°COIL RPM | 20°COIL RPM | IR DROP | CEMF | RPM | IR DROP | CEMF | RPM | IR DROP | CEMF | 20°COIL RPM | 60°COIL RPM |
| 2520 | 300 | 25 | 275 | 600 | 1800 | 10 | 290 | 1440 | 10 | 290 | 1440 | 30 | 270 | 1440 | 360 |
| 2100 | 250 | 25 | 225 | 500 | 1500 | 10 | 240 | 1200 | 10 | 240 | 1200 | 30 | 220 | 1200 | 300 |
| 1680 | 200 | 25 | 175 | 400 | 1200 | 10 | 190 | 960 | 10 | 190 | 960 | 30 | 170 | 960 | 240 |
| 1260 | 150 | 25 | 125 | 300 | 900 | 10 | 140 | 720 | 10 | 140 | 720 | 30 | 120 | 720 | 180 |
| 840 | 100 | 25 | 75 | 200 | 600 | 10 | 90 | 480 | 10 | 90 | 480 | 30 | 70 | 480 | 120 |
| 420 | 50 | 25 | 25 | 100 | 300 | 10 | 40 | 240 | 10 | 40 | 240 | 30 | 20 | 240 | 60 |
| 210 | 25 | 25 | 0 | 50 | 150 | 10 | 15 | 120 | 10 | 15 | 120 | 30 | −5 | 120 | 30 |

**Figure 3 — Chart showing relation of IR drop to total voltage over wide range of speeds.**

tially consists of an uncoiler, a shear, a welder, a scrubbing tank, a dryer and rinse tank, a pulling pinch roll, a drag bridle and a reel.

The strip is delivered to the cleaning line from the cold mill in coils of varying diameter. These coils are placed on the uncoiler, threaded through the cleaning tank and entered in the pinch roll, then a loop is formed and the strip is threaded through the bridle rolls, entered and clamped on the reel. As the strip is only a few thousandths of an inch thick, the tension and speeds between the various units must be accurately controlled to avoid whipping or developing kinks. As the maximum delivery speed of these lines is increased this becomes more and more important.

About the only work being done by the motors is that required to pull the strip through the line. This is an excellent example of a constant torque application, which means that the horse power requirements of the motor is almost directly proportional to the speed of the strip. This is, therefore, an ideal application for variable voltage operation and control of the motors.

When it is considered that 150 hp is required for the reel and that the strip is traveling at a maximum speed of 2,500 fpm, it becomes readily apparent that a mechanical drag or tension device would no longer be practical because of the excessive maintenance involved. This means that the drag bridle and the uncoiler must furnish their back tension electrically instead of mechanically.

Another factor which must be recognized is the build-up of both the uncoiler and the reel. In many instances this build-up is 3 to 1 which means that at a constant line speed the uncoiler and reel speeds must vary over a range of 3 to 1. Since the tension must be controlled, as well as the speed, some additional range is necessary for regulation. It is, therefore, necessary to have at least a 4 to 1 range motor for this application. The ideal solution to this problem is, of course, variable voltage control which permits voltage control of the line or strip speed and field control of the uncoiler and reel, to take care of the coil build-up.

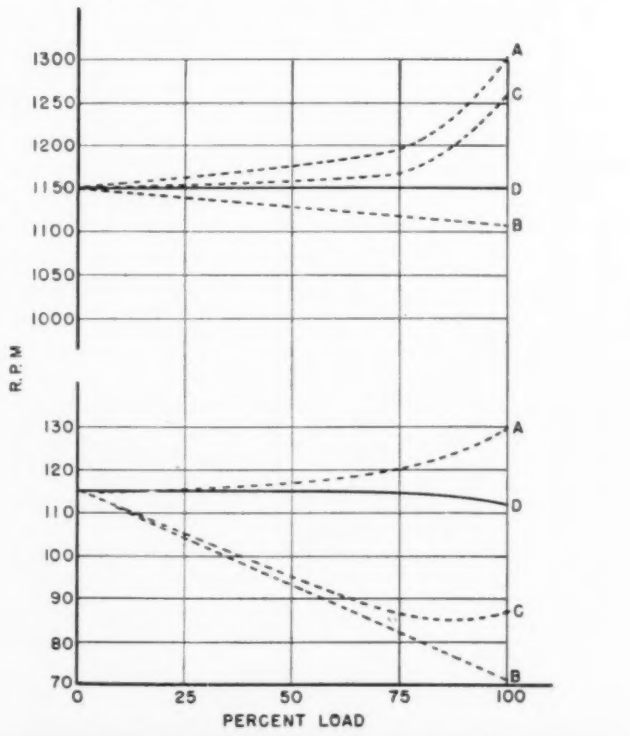
The problem is further complicated, however, by the fact that in effect we have two independent lines or units connected by a loop which must operate in tandem. Again referring to Figure 1 we will see that the pinch roll pulls the strip through the cleaning line and that tension in the strip is maintained by the uncoiler acting as a drag generator. This may be considered as our first unit or entry end. On the other side of the loop, however, we have a reel which is coiling the strip delivered from the loop and against which tension is maintained by the bridle roll acting as a drag generator.

Usually there is approximately 10 feet of strip in the loop. With a line running at 1000 fpm or 16.7 fps, we would have 0.6 second running time available in the loop. However, when we increase the speed of the line to 2500 fpm or 41.7 fps we find that we only have 0.24 second running time in the loop. This means that our two units must operate almost exactly in synchronism and also that any difference in speed be adjusted almost instantaneously.

As it would be both impractical and uneconomical to rethread the line for each coil and would also greatly interfere with production, it is necessary that the entire line be stopped at the end of each coil, a new coil welded to the tail end of the previous coil, and the line again brought up to speed. A similar procedure must be fol-

**Figure 4 — Curves showing effect of armature demagnetization, IR drop and proper compensation. Upper curves at full voltage, full speed. Lower curves at one-tenth voltage, one-tenth speed.**

CURVE A – EFFECT OF ARMATURE COIL DEMAGNETIZATION.
CURVE B – EFFECT OF IR DROP.
CURVE C – EFFECT OF ARMATURE COIL DEMAGNETIZATION LESS IR DROP.
CURVE D – EFFECT OF DEMAGNETIZATION LESS IR DROP AND SERIES FIELD DROP.



lowed each time the reel has to be stripped. This means that the line must accelerate from 0 to 2,500 fpm and at the same time maintain constant tension, or nearly so, between the uncoiler and the pinch roll; maintain the loop between the pinch roll and the bridle roll; and also maintain constant tension between the bridle roll and the reel.

Because of the widely varying inertias of the various drives, the loads, particularly during acceleration and deceleration, are not uniform. For this reason, if we are to successfully operate this line, we must have a flat speed regulation for all of the motors which can in any way affect the speed or synchronization of the line.

This problem of a flat speed regulation over a wide range of loads and speeds is not new. The methods of compensation necessary to obtain it were developed in extending the operating range of tandem cold mills. Since previous papers have already been presented on this subject, we will not attempt a discussion of the principles involved at this time.

Our problem, therefore, becomes one, not of developing new methods of compensation, but rather, that of extending the present methods to wider ranges and more exacting conditions. The basic scheme, shown in Figure 2, is still to use a direct connected compensating exciter and an IR drop booster.

Since the strip, to be cleaned, is usually only a few thousandths of an inch thick it is impractical to use side guides as they would very likely damage the edges of the strip. Because of this we have to use tension between the uncoiler, and the pinch roll to insure that the strip will track properly through the cleaning tanks. The necessary tension required for smooth operation of the entry end of the line is set by the operator and maintained by a constant current regulator. This practice provides smooth operation even though the uncoiler speed is constantly changing due to the coil build-up.

If it were possible for us to replace the pinch roll with the reel, our problem would be greatly simplified. Because we could then pull the strip through the line and coil it, while at the same time maintaining constant back tension with the uncoiler. Because the coils are usually stacked on end in the annealing furnace it is important that the edges be maintained in a uniform plane. If there is any marked irregularity between the layers of the coil, the edges are usually damaged by the handling necessary between the cleaning line, the annealing furnace, and the temper pass mill. These bad edges cause considerable trouble when the strip is uncoiled during the temper pass process resulting in slower speed operation and greatly reduced production at this point.

The need for coils with smooth, even edges is responsible for the addition of the loop and the bridle rolls to a cleaning line. The bridle rolls are usually slightly crowned or operated to produce the same effect as crowning. This crowned effect serves to guide the strip, providing it is free on the entry side. In this case, the loop provides the free end which is guided by the bridle roll and coiled with uniform edges by the reel. The strip, of course, must be coiled under tension to accomplish this. Here, again, a tension regulator is used between the bridle roll and the reel to maintain the proper tension.

The method shown in Figure 2 constitutes a complete and simple one for maintaining predetermined speed relationships under all conditions as required on the present day cleaning line. The driving motors operate at all times as though they were under no load, as each disturbing influence is counteracted by a compensating device that directly offsets any tendency to cause the motor to change its speed with load.

As previously stated, the problem of providing electrical equipment, for the present day cleaning line is far more difficult than it was a few years ago. Accelerating and decelerating from 0 to 40 fps imposes entirely different conditions on motor equipment than with a running speed of less than 15 fps. Over such wide speed ranges the commutated armature coil demagnetization becomes almost zero while the IR drop of the armature circuit of the motor may become equal to and even greater than the generator voltage. The motors would stall under such a condition and the drag generators would release their tension. Figure 3 with its sample calculations indicate what percentage of the voltage the IR drop may be and also the speed range over which the various machines must operate in synchronism.

Threading and operating at reduced speeds, which are necessary when bringing the weld through the line, or when cleaning a coil with bad edges, have been among the most difficult problems. The electrical phase of this application has been solved by compensation for armature coil demagnetization and IR drop.

Figure 4 indicates how well we have succeeded in the solution of this problem. The upper set of curves show the effect of armature demagnetization, IR drop, and proper compensation on a typical motor at full voltage and full speed. The lower set of curves show these same effects on the same motor at one-tenth voltage and one-tenth speed. It is evident that with proper compensation it was possible to obtain flat speed regulation from no load to full load at full voltage. With this same compensation, it was possible to obtain speed regulation of about 3 per cent at threading speed or one-tenth voltage.

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# Developments in CONTROL Equipment and Devices

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*. . . . a review of some of the improvements in electrical control equipment, including electronic control, which can be expected to receive broader application . . . .*

Presented before A. I. S. E.

PHILADELPHIA DISTRICT SECTION

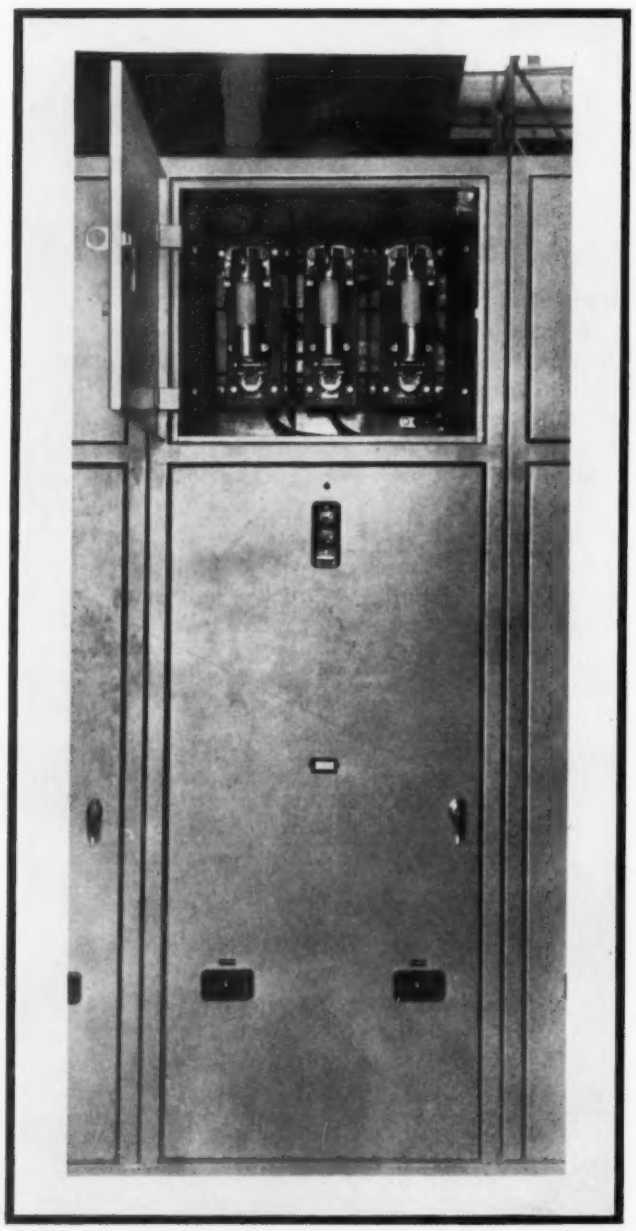


**Figure 1 — Metal-enclosed, high interrupting capacity, induction motor controller with current-limiting fuses.**

▲ WE are fortunate to be able to tell of any real developments at all, because of the abnormal burden placed by the emergency on manufacturing facilities and engineering talent. It is gratifying, therefore, that some small amount of time and talent has been expended on new developments for industry in general, and this paper is offered as a review of some of the accomplishments.

For the sake of having some means of classifying the recent developments in control, I have chosen to follow the more or less natural subdivisions into which this broad-gauged subject divides itself. The following is such a classification:

1. High voltage a-c control.
2. Low voltage a-c control.
3. D-c control and accessory devices.
4. Electronic control.

## High Voltage A-c Control

The recent developments in the field of industrial control equipment for a-c circuit voltages above 600 volts have been largely brought about by a more serious respect for, and an intelligent study of, the effects of fault currents on previously existing designs of apparatus. The rapid industrial expansion, with its increasing demand for electrical power, has resulted in a general "stiffening" of power supplies in this voltage range. This means a greater system kva capacity with

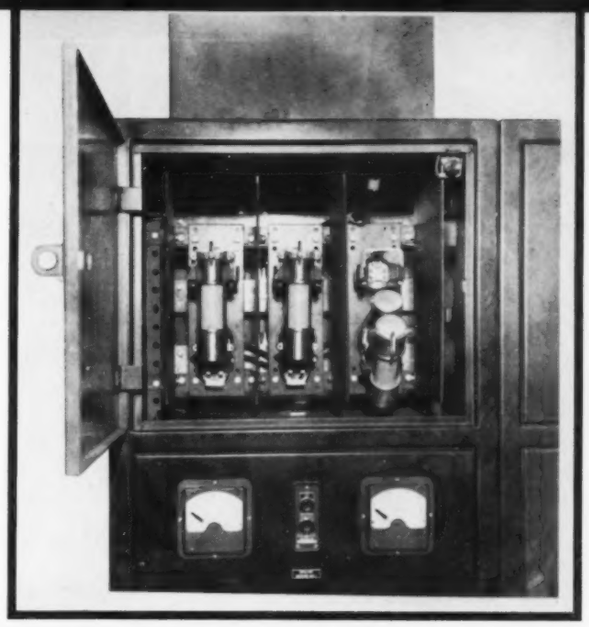


**Figure 2 — Enclosed magnetic six-unit synchronous motor control. Fuses act as disconnects.**

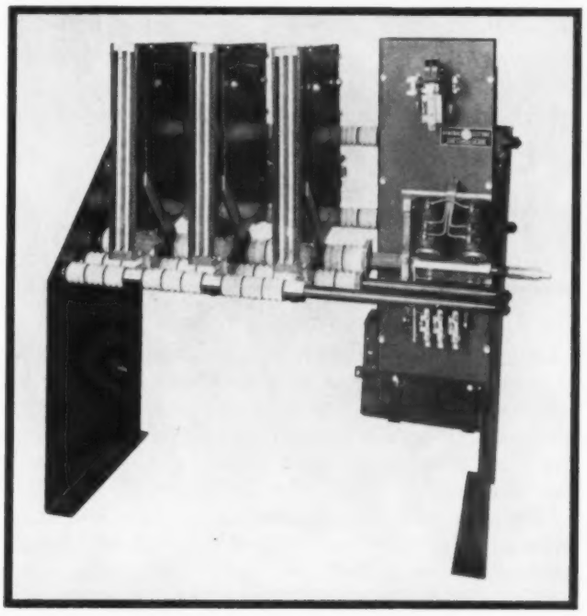
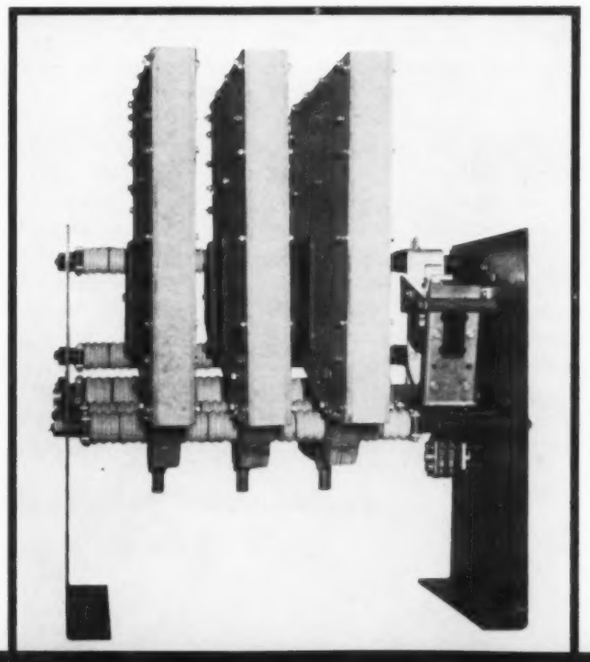


**Figure 3 — Conventional high voltage air break a-c contactor, with d-c operating coils for time-delay dropout.**

**Figure 4 — View showing construction of high voltage air break contactor.**



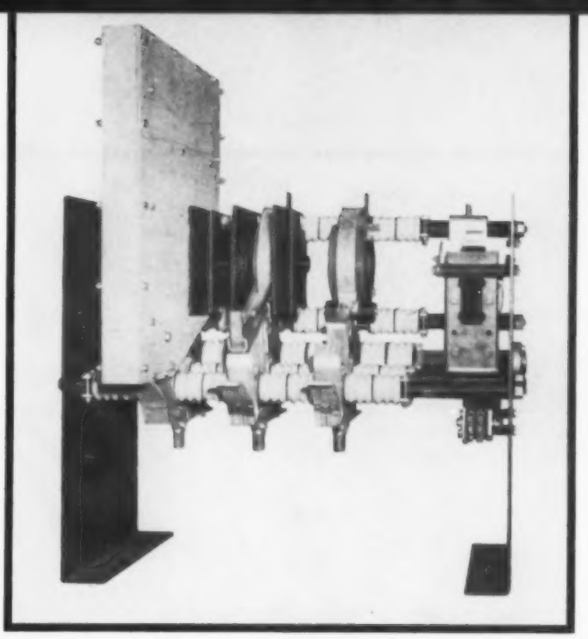


**Figure 5 — High voltage air break contactor without arc chute on center pole, and chute, pole pieces and arcing horn on right pole.**

the resultant elevation of available system fault current. In high voltage a-c circuits, the current that can flow in a short circuit is higher than on a low voltage circuit because of the lower impedances in the circuit. A very "stiff" industrial power system in this voltage range might make available fault currents ranging from 50,000 to 100,000 amperes, whereas in more moderately sized industrial plants, short-circuit currents in this same voltage range might vary from 5,000 to 20,000 amperes.

*Metal-enclosed 2,200-volt motor control with short-circuit protection* — The recent development of a successful current-limiting power fuse has made it possible to design a coordinated, metal-enclosed, 2,200-volt motor starting equipment with inherent short-circuit protection. By very definition, a motor-starting equipment must inherently be a long-life device, capable of frequently repeated starts. This implies a design which has long mechanical and electrical life, as is typical of most industrial control motor-starting equipment. However, it is beyond the definition of an industrial control device to protect the motor or motor conductors between starter and motor from fault currents. Therefore, if a coordinated design of a long-life motor-starting equipment, together with inherent short-circuit protection can be integrated into one equipment, a very definite step forward has been made in the high voltage control classification.

Such an equipment is shown in Figure 1. This equipment is recommended for installation on circuits where initial asymmetrical rms amperes capable of being produced by the system are not in excess of 80,000 amperes at 2,300 volts, 60 cycles. This new coordinated control utilizes a specially built long-life contactor for starting the motor, and current limiting fuses for providing short-circuit protection. Because of the current-limit effect of the fuses and the speed with which they interrupt the circuit, the specially built contactor, current transformers, and overload relays will withstand the relatively small current which flows through them. The fuses are mounted in hinged support and act as a disconnecting means (Figure 2).

Such equipments are available for squirrel-cage, syn-

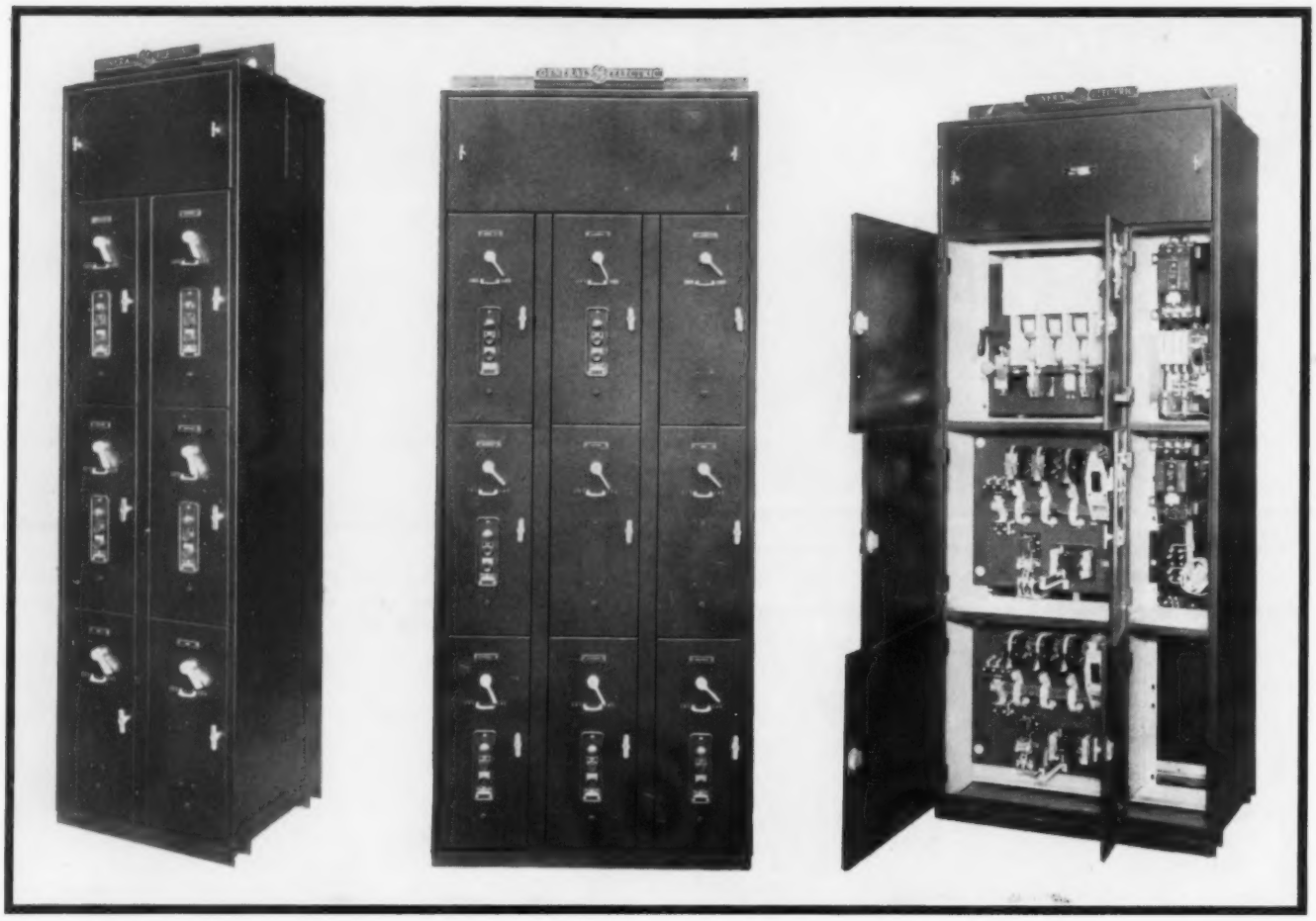
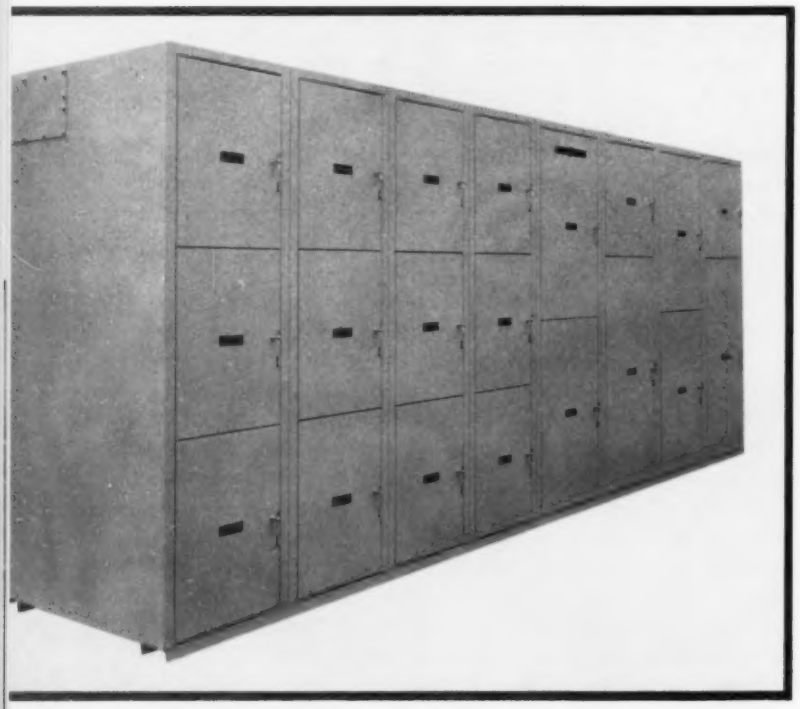


**Figure 6 — Dead-front magnetic cabinet panel, approximately 25 in. wide.**

**Figure 7 — Dead front magnetic cabinet panel, approximately 38 in. wide.**

**Figure 8 — View, with doors open, of a cabinet panel used for controlling boiler auxiliaries.**

**Figure 9 — Enclosed draw-out type contactor control board for 440 volt power station auxiliaries.**



chronous, and wound-rotor induction motors operating on 2,200-volt, 60-cycle circuits. Some of the notable features are a built-in windlass for lowering the oil tank of the contactor; segregated high voltage circuit; and a complete self-supporting floor-mounted cabinet-type enclosure.

*High-voltage air-break contactors* — It is a well-established scientific fact that whenever metallic contacts are operated under oil and subjected to electrical arcing, the rate of loss of weight of the contact material is much higher in oil than it is in air. This can become a serious problem on a high-duty cycle application, resulting in short life of contact tips. Moreover, in an oil-immersed contactor, the oil acts as a dual-purpose medium in the role of arc extinction. First, the hydrostatic pressure of the oil is helpful in extinguishing the arc and, second, the dielectric value completes the job. But the oil is subject to the contaminating effect of the arc, due to the fact that particles of carbon are "cracked" from the oil by the heat of the arc and are disbursed throughout the oil, lowering its insulation value. Eventually, the oil may arrive at a condition where its insulation value is so poor that it is not only of less help in interrupting the arc, but may actually constitute a hazard as phase-to-phase insulation within the same oil tank.

However, in spite of all these recognized shortcomings and in spite of the typical obituary of many oil-immersed, high-voltage starters, the field of application of high-voltage air break a-c contactors has been quite restricted. Outside of the mine hoist primary contactor application, high-voltage air break contactors have had very limited use. Perhaps one of the former reasons for

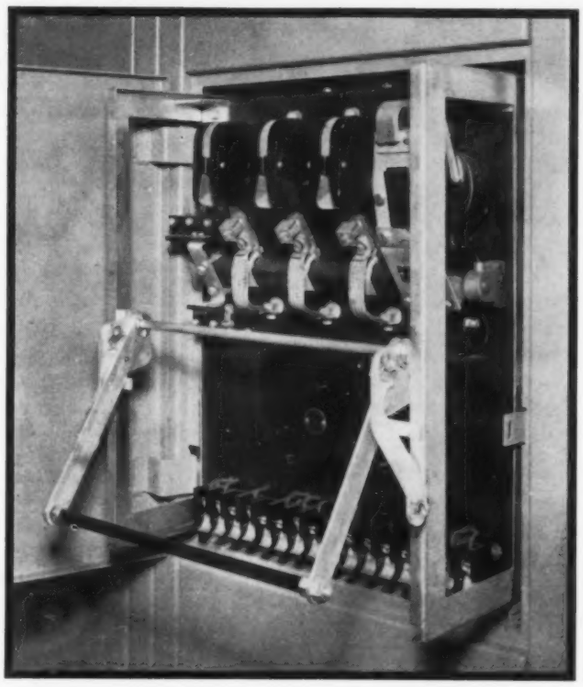


**Figure 10 — View showing 150 amp panel partially removed from enclosed draw-out type contactor board.**

its limited use has been its rather poor space economy. This was imposed by wide pole spacing between adjacent phases and the necessity of maintaining larger striking distances between contactor arc chutes and adjacent enclosures. Figure 3 shows a conventional high-voltage air break a-c contactor.

Recent knowledge obtained from the constant studies of the properties of arcs in air and their extinction, has made it possible to design a three-pole, high-voltage a-c contactor capable of meeting the space factor requirements for standard metal-enclosure mounting without sacrifice of phase insulation or the danger of ionized vapors coming in contact with the enclosure. Improvement and coordination in the arc extinguishing structure have made possible this development. Figure 4 shows its construction. Moreover, this contactor when used in conjunction with current-limiting power fuses will provide a superior high-voltage motor-starting equipment, completely metal enclosed, with inherent short-circuit protection, which will be absolutely oil-less. Figure 5 shows two arc chutes removed.

### Low-Voltage A-c Control

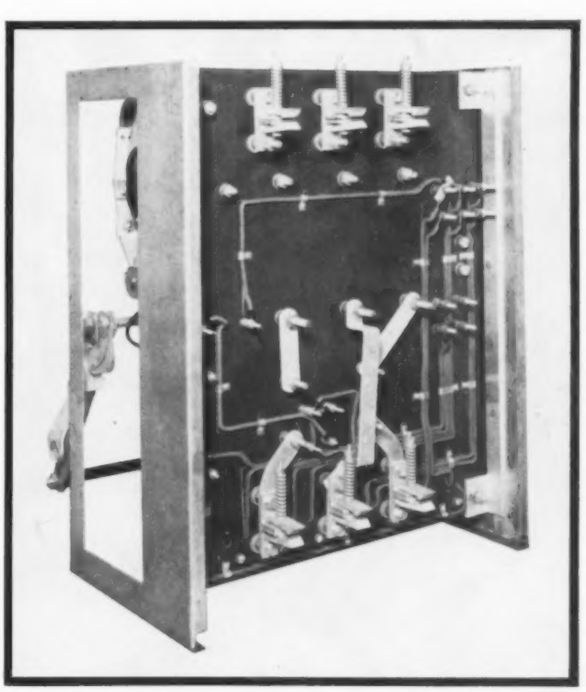
Although on alternating current systems of 600 volts and below, the available system fault currents are usually less than on high-voltage circuits, there is a marked trend toward providing adequate short-circuit protection to low-voltage a-c control equipment.

*Motor control centers* — To meet an increasing demand for centralized and group assembled motor control equipments, capable of extreme flexibility both during and after installation, a completely standardized system of motor control centers was established. Essentially, they offer dead-front, totally enclosed, cubicle-mounted units with the ultimate in interchangeability and compactness so that a "custom-tailored" arrangement can be made without the expense and time required for engineering previous types of custom-built cubicle construction.

Various section widths with a further subdivision of this section into groups capable of accommodating different N. E. M. A. sizes of motor-starting equipment are available. These individual compartments are available to cover N. E. M. A. sizes from size 0 to size 5 inclusive and have sufficient space to incorporate therein branch-circuit protection and a motor circuit switch. Two sections of different widths are shown in Figures 6 and 7 with the widest section shown in Figure 8. This widest section accommodates three size 2 compartments and three size 4 compartments. Thus, in a section 38 in. wide by 24 in. deep by 90 in. high, it is possible to centralize control for three 100-hp, 440-volt, 3-phase, 60-cycle motors and three 25-hp, 440-volt, 3-phase, 60-cycle motors. Complete wiring to a motor feeder circuit bus is also provided. The appearance of these units is pleasing.

*Draw-out type motor control centers* — Pursuing the motor control center idea still further, though sacrificing flexibility in order to obtain a higher degree of serviceability, we find the development of draw-out low-voltage control centers of interest. In the field of power generation, many auxiliary drives such as pumps and fans are required. Not only must they be the ultimate in reliability but be capable of quick servicing or

**Figure 11 — Rear view of 150 amp panel from enclosed draw-out type contactor board.**



entire replacement should difficulty arise. Furthermore, these motor controls are usually required to stand higher levels of fault currents than are encountered in most industrial plants, with some of the controls even having sufficient interrupting capacity to work in conjunction with an instantaneous-trip overload relay, thus providing inherent short-circuit protection. One such arrangement as described above is shown in Figure 9. The draw-out and latching-in features of the individual motor starter are shown in Figure 10. Current-carrying portion of the disconnecting plug on the removable section is shown in Figure 11.

*Dead-front motor starters for induction and synchronous motors* — A trend in the direction of better safety as well as improved appearance has manifested itself in the development of dead-front motor-starting equipment for those horsepower ratings requiring in general, self-supporting, floor-mounted panels. An example of a new construction to meet this trend is shown in Figure 12. This construction bids to be the standard of the future.

*Control for corrosive and hazardous atmospheres* — The unprecedented activity with resultant plant expansion in the chemical and oil refining industries has stimulated a great demand for low-voltage motor-starting equipment capable of successful performance in an atmosphere which is either corrosive or explosive, or both. The related line of oil-immersed combination motor starters is illustrated by a typical size 2 starter in Figure 13. With the oil tank lower, Figures 14 and 15 show contactor and motor circuit protection in the form of a circuit breaker, for a size 3 starter.

To afford short-circuit protection to motor, motor conductors, and the starter, this oil-immersed circuit breaker has demonstrated, by actual test, its ability to protect on systems capable of furnishing 20,000 amperes fault current when coordinated with the induction-thermal overload relay, which provides running overload protection. The induction thermal relays are electrically reset.

**Figure 12 — Dead-front magnetic controller for 250 hp, 440 volt synchronous motor.**

▲

**Figure 14 — View showing construction of oil-immersed switch shown in Figure 13. All terminals and arcing parts are under at least 6 in. of oil. (center)**

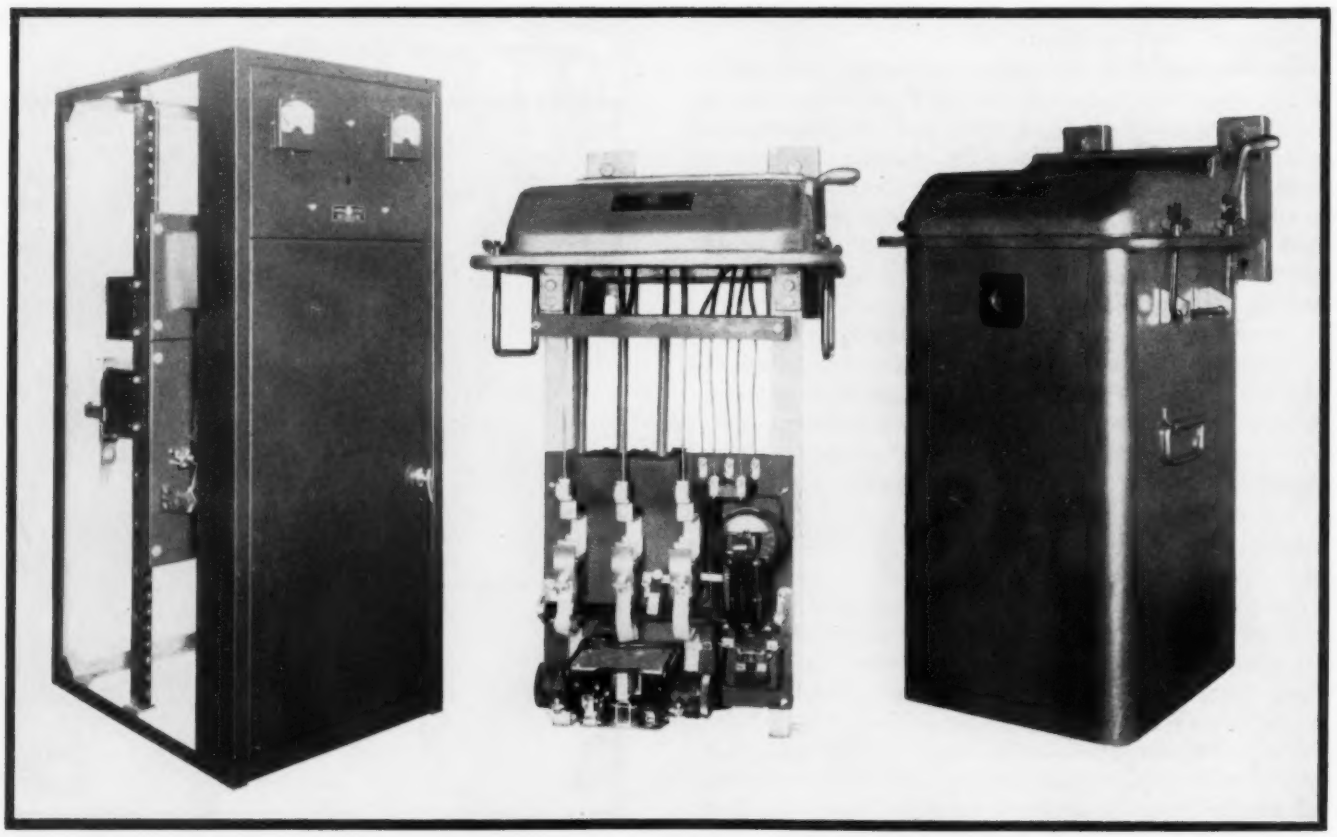
▲

**Figure 13 — Oil-immersed combination magnetic switch designed for hazardous gas location.**

## D-c Control and Accessory Devices

This subdivision of the control field includes, by far, the greatest number of devices and equipments in which steel mill men are interested. In fact, it embraces nearly all the group auxiliary drives as well as the material handling problems such as crane control and accessory machine drive.

*D-c accelerating contactor with magnetic time* — As might be expected in these times, one of the most important developments in this group was a contribution to the d-c control used chiefly in the machine tool field, although its use is not strictly confined to that service. The development of two new d-c contactors for accelerating service which performs the dual function of a contactor and a magnetic time acceleration relay has made possible a reduction in the size of direct-current



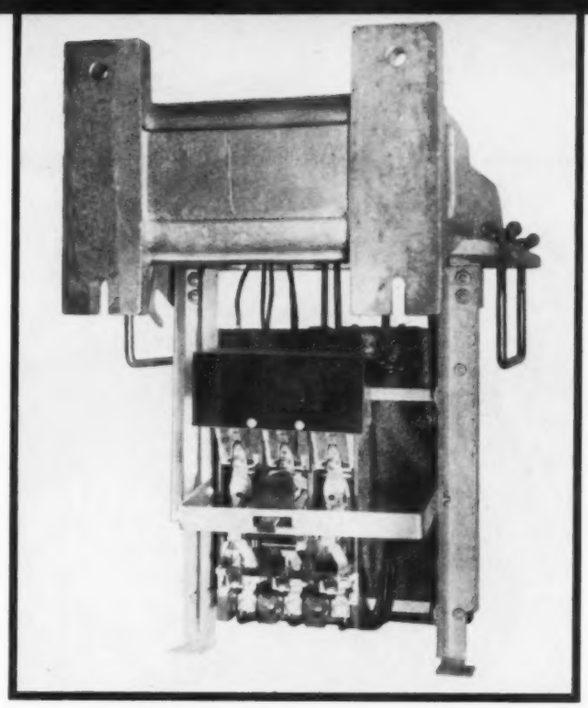


**Figure 15 — General purpose oil-immersed combination magnetic switch designed for use in corrosive atmosphere.**

**Figure 16 — Direct current accelerating contactor rated at 550 volts, 100 amperes.**

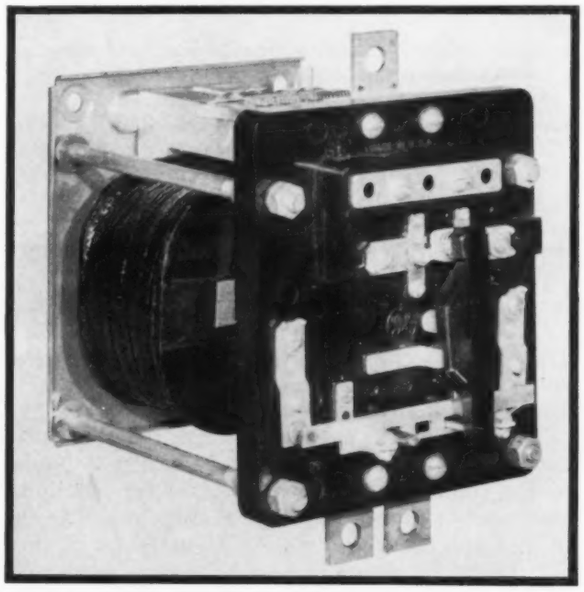
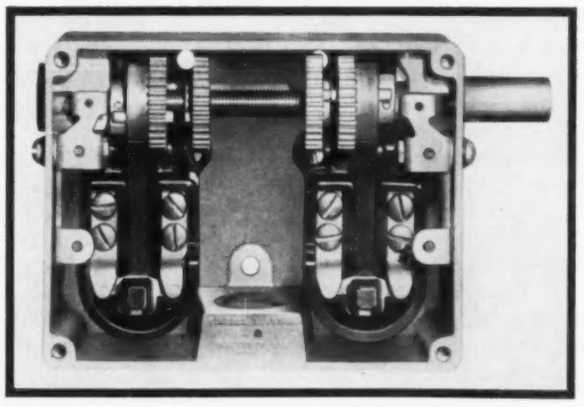


**Figure 17 — Enclosed geared double-break contact limit switch, with cover removed.**



starters to as much as 50 per cent. Figure 16 shows this construction.

The contactor consists essentially of either two or three separate and independent magnetic structures actuated by a single two-part coil. The contactor is energized on full voltage on starting and all the contacts then open. A holding-in section of the coil is energized by the discharge from a capacitor and, as the charge in the capacitor is dissipated, the fingers of the contactor close, one after the other. The time ratio between the closing of the poles is varied by spring pressure and magnet gap adjustment. The two new d-c normally closed contactors are rated 50/100 amperes, 2 pole, and 100/150 amperes, 3 pole.

Other important d-c contactors for machine tool applications having extreme flexibility of modification, and offering space saving are well on the road to production.

*Crane control* — Developments need not be actual equipments or devices. They may be conditions encountered in service which must be considered in designs of the future. Such an example is found in the crane hoist control field.

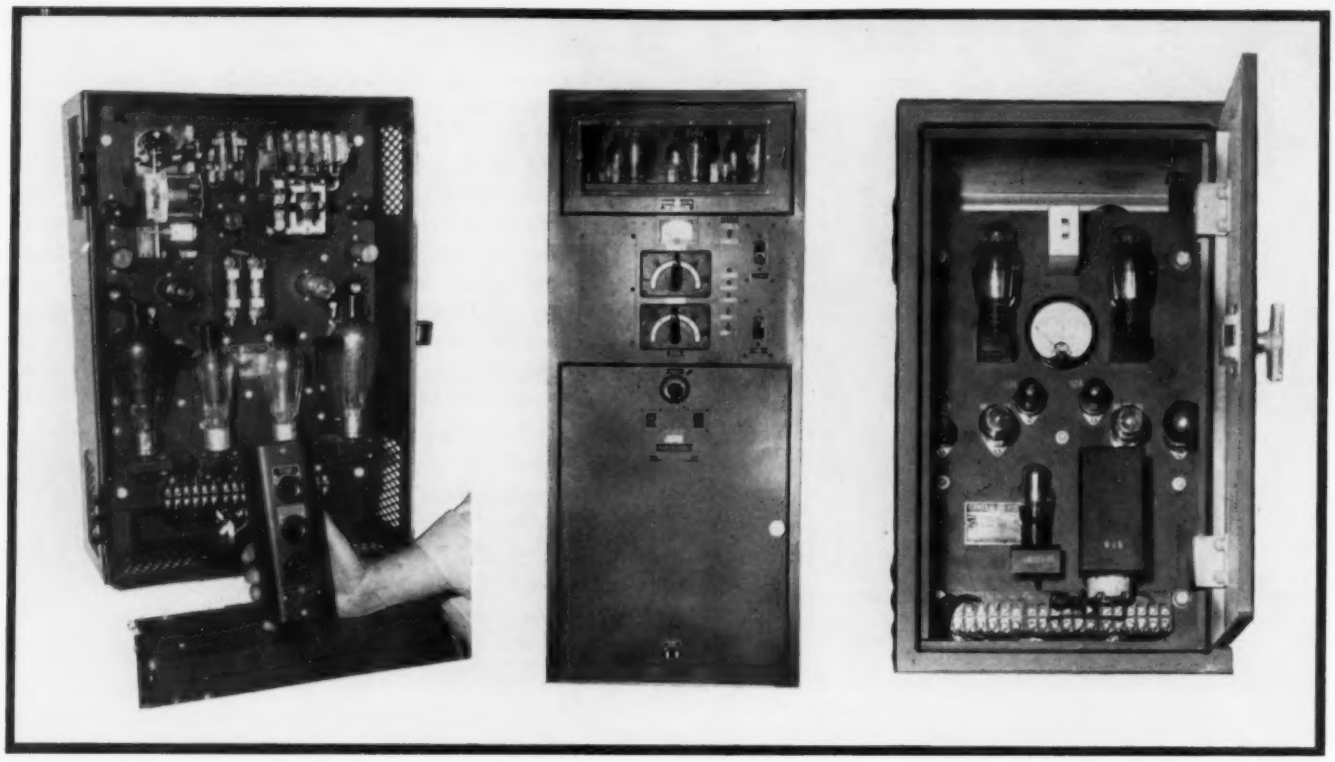
With the improved mechanical efficiency of modern cranes due to improved gearing, machining, and lubrication, the motor speeds which can exist at the time a hook block operates a power-type hoist limit switch are higher than ever. This condition of motor speed necessitates increasing the resistance in the dynamic braking circuit established by the limit switch, so that the motor will commutate its dynamic braking current. Furthermore, the hook block enters the limit switch a greater distance because stored energy varies as the square of the speed.

Now, this improved mechanical efficiency requires little or no torque to lower an empty hook out of the tripped limit switch zone. The circuits established for lowering from a tripped limit switch are those of a shunted series motor which can develop no dynamic braking torque. It follows that if a load is being lowered, the overhauling torque may take the motor to a high speed before the limit switch resets.

This has brought about the necessity for a control scheme to improve safety by preventing overspeeding lowering.

*Limit switch* — Figure 17 shows a recent development in the geared type of limit switch which offers a unique principle to facilitate rapid adjustment without disconnection from the mechanism which drives the limit switch, or without the necessity of moving the rotating equipment to which the limit switch is connected.

The mechanism is of the traveling geared type, the adjustment of which is easily made by simply depressing a small lever which releases the shaft on which the traveling gear is mounted, and rotating the traveling gear to the desired position. A wide range of adjustment (½ to 120 turns) is provided with an additional 3½ turns for allowable over-travel. Accidental rotation beyond the 3½ over-travel current will not be harmful to the switch and will simply pry the shaft upward against the spring of the lever which retains it in position. The enclosures are of cast iron with mounting provisions made inside the enclosure. To meet the demands for a



small compact direct-connected limit switch for watertight and explosion-proof construction, this limit switch is admirably suited.

**Figure 18 — Control station, transformer, and thyratron tube panel comprising electronic motor control.**

**Figure 19 — Resistance-welding control, showing tubes, capacitor tap switch, voltage-capacitor tap switch, adjusting potentiometer, indicating lights and protective breakers.**

**Figure 20 — Current regulating compensator for use with thyratron resistance-welding control panels.**

### Electronic Control

No longer is one able to set apart the electron tube from its justly deserved place in industrial control problems. In fact, in many modern equipments, it is now the only "line of communication" between those tiny amounts of energy, which tell of certain conditions existing in some process requiring control, and the brute-force conventional magnetic control.

Consider, for example, the measurement and control of:

1. Heat energy.
2. Speed control as a function of tension.
3. Speed control as a function of some other means.
4. Positioning control, etc.

In other words, the electron tube lends a helping hand in a noiseless, high-speed, inertia-less manner to those signals so weak as to be incapable of use by conventional control, by amplifying them to usable levels where conventional control can take over.

*Electronic motor control* — The control of motors by supplying power to them from an electron tube is not a new art. The recent announcement of a completely coordinated wide-range adjustable speed drive, using electron tubes as controlled rectifiers, marks a new high in the electronic field. Such an equipment is shown in Figure 18 and has been given the trademark "thy-motrol."

In its simplest form, this electronic motor control consists of an electron tube control panel, a transformer, and a push-button station. With the motor this equipment makes a unique, variable speed drive offering several outstanding features not provided by more conventional types. Complete control of the motor is accomplished without rotating parts.

Electron tubes convert alternating current to control direct current used for operating a d-c motor. Two tubes provide voltage to the armature and two additional tubes supply voltage to the field of the motor. The output of these tubes is controlled by a group of small control tubes in such a manner as to provide starting, accelerating, and wide speed range of the motor. The control also provides equipment for dynamic braking, thermal overload protection, undervoltage protection, and, when required, reversing by the addition of a standard magnetic reversing switch.

A simple single-dial speed-control unit varies armature voltage at speeds up to basic and field currents at speeds above basic, so that it is possible to operate the motor over a wide range of speeds. The current-limiting characteristic permits the motor to accelerate at the maximum possible rate without overloading either the control or the motor. Operating speed can be preset and since the system provides closely regulated armature voltage and compensation for armature voltage drop, motor speed is held constant within close limits independent of the load and ordinary line voltage variation. Standard units are available up to 5 hp at 230

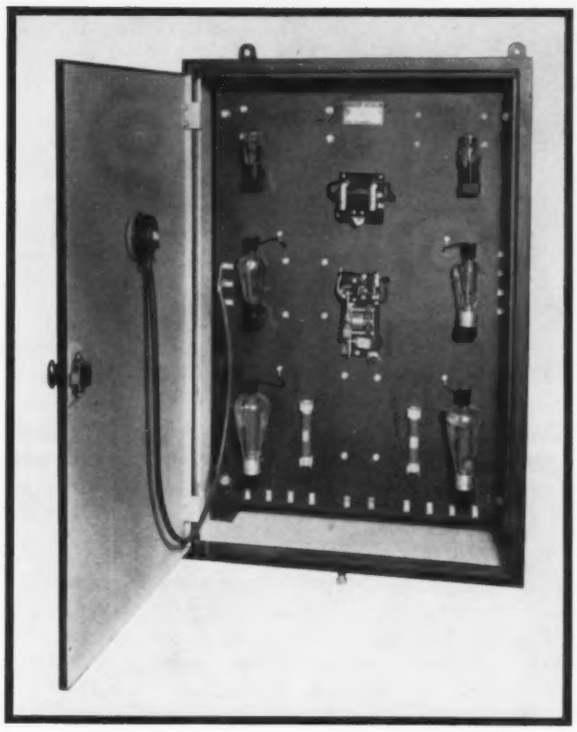


**Figure 21 — Enclosed voltage regulation compensating panel for use with thyratron welding control.**

volts for operation from a single-phase power supply of any standard commercial voltage or frequency.

*Resistance welding control* — Primarily because of its reliability and the time saved in metal fabrication by its use, resistance welding has become of increasing importance to the defense program. The savings achieved by its use in aircraft fabrication are outstanding.

The capacitor discharge control, designed for use with energy storage resistance welding machines used principally by the aircraft industry, is shown in Figure 19. This control includes a high voltage rectifier, tap switches, voltage adjuster and the capacitors, all mounted in a single cabinet.

Whenever magnetic materials are moved in or out of the throat of a resistance welding machine, the resulting change in impedance causes a corresponding change in the welding current. In order to eliminate this change in current, a compensator known as the "current regulating compensator" compensates the variations in impedance or line voltages and tends to hold the welding current constant regardless of these variations. This particular compensator is limited to those applications where the welding time is 20 cycles or longer. Figure 20 shows such an equipment. The second type, known as the voltage regulating compensator, holds the welding current constant for variations in line voltage, (Figure 21). The third type, known as the voltage compensator, is similar to the voltage regulating compensator except that it is not as accurate; however, the control is appreciably simpler.


### Summary

The foregoing review represents only some of the more important developments in a wide variety of industrial equipments. Obviously, there are many other important one for our defense projects about which nothing can be said. However, it is hoped that experience with new designs rapidly brought into production for defense use will provide a wealth of experience and new thinking for better industrial control when the emergency has passed.


# DISCUSSION


PRESENTED BY

**G. O. VAN ARTSDALEN, Superintendent, Maintenance, Henry Disston and Sons, Inc., Philadelphia, Pennsylvania**

**H. H. ANGEL, Electrical Department, Bethlehem Steel Company, Sparrows Point, Maryland**

**E. H. ALEXANDER, Engineer, Industrial Control Division, General Electric Company, Schenectady, New York**

**J. W. COOKE, Industrial Control Engineering Department, General Electric Company, Schenectady, New York**


**G. O. VAN ARTSDALEN:** There is only one question that I would like to ask. We have been interested for a long time in the possibility of getting away from the oil immersed high voltage equipment and we have seen some of this new equipment for voltages up to 5000, much of which uses auxiliary services, compressed air, etc. I would like to ask Mr. Alexander just what is the tops on current carrying capacity, and interrupting capacity, as well as the top voltage that can be used without the use of any arc-extinguishing auxiliary equipment.

**H. H. ANGEL:** Mr. Alexander mentioned that on some of the newer cranes there is a possibility of obtaining a high speed when lowering the hoist after the limit switch has cut out, and of continuing to have that high speed until the limit switch resets and places the power circuit under normal dynamic breaker lowering. I'd like to know just what difficulties have been encountered in the industry with that, and I'd like an expression, also, from some of the other manufacturers, if you can give it very briefly. Personally, I do not recall having had any trouble like that because generally the hoist limit switch cuts out when the empty block is going up. It is very seldom that it is called upon to function, hoisting a heavy load.

The other question I have is about getting unstable high speeds when handling very heavy loads. Is there any provision being made in the latest control to take

care of that condition so that the operator is not held entirely responsible for that over-speed condition?

**E. H. ALEXANDER:** Mr. Van Artsdalen asked about the high voltage contactor. The first question was the current rating which I presume means the normal 8-hour current-carrying capacity; the second the voltage range, and third the interrupting capacity.

The one shown in Figure 4 has a continuous carrying capacity of 200 amps. Because it is an industrial control device used as a motor starter or a contactor, it has 10 times normal interrupting capacity only — but when used in conjunction with the current limiting power fuse it is then capable of installation on systems whose short-circuit capacity would be equal to 46,000 symmetrical rms amperes. The voltage is 2300 volts.

Now there are a number of outstanding high voltage air break contactors on terrific duty cycles at 6600 volts, but they have a double break per phase.

**J. W. COOKE:** To best answer the question of Mr. Angel regarding crane hook operation out of a tripped overhoist limit switch, I will refer to the accompanying illustration which shows some of the power circuits of a typical hoist controller.

Figure 1 illustrates the basic lowering connections of a dynamic braking hoist controller. The four contacts of the limit switch are identified as (1), (2), (3) and (4). The switch is shown in its normal running position with contacts (1) and (2) closed and (3) and (4) open. The motor is connected as a shunt machine and either motor or dynamic braking torque is developed depending upon load conditions.

Figure 2, with the exception of the circuits shown dotted, illustrates the basic connections established when lowering out of a tripped limit switch. Here the set-up is such that the armature and series field are in series through limit contact (3). The motor (armature and field) is shunted by resistor section $R_{ls}$ through limit contact (4). Under this connection, no dynamic braking torque is developed.

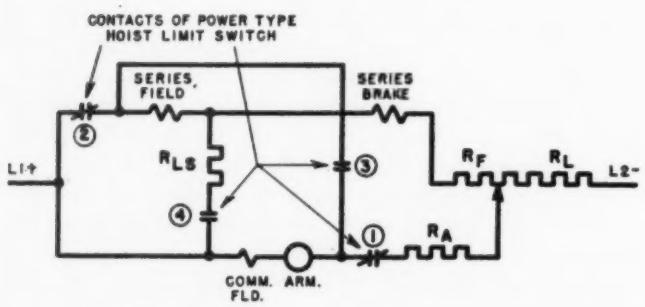
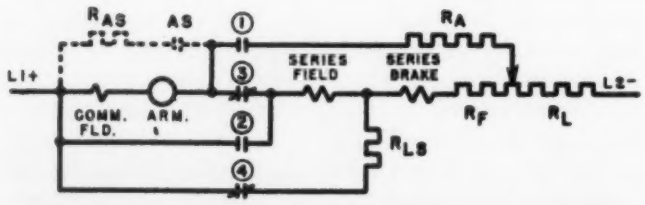



**Figure 1 — Basic lowering connections of dynamic braking hoist controller, (limit switch contacts shown in normal running position).**

**Figure 2 — Basic connections when lowering out of a tripped limit switch.**




As pointed out by Mr. Alexander, the improved mechanical efficiency of modern cranes has made it necessary, in some cases, to increase the ohms in limit switch resistor $R_{ls}$ so that the motor can better commutate the dynamic braking current which flows when the switch is tripped under light-load, high-speed, operation hoist.

As may be seen from Figure 2, increasing the resistance of section $R_{ls}$ causes more current to flow through the motor when lowering out of the limit switch. This results in more torque for acceleration. Since the torque of the motor and the pull of the load are in the same direction, a high lowering speed is quickly attained. This is just the reverse of what is needed for good operation.

Now when the hook block reaches the end of the limit switch zone and the switch resets, normal dynamic braking connections, as shown by Figure 1, are established. The resultant sudden slow-down subjects the hoist mechanism and the entire crane to high strains and stresses.

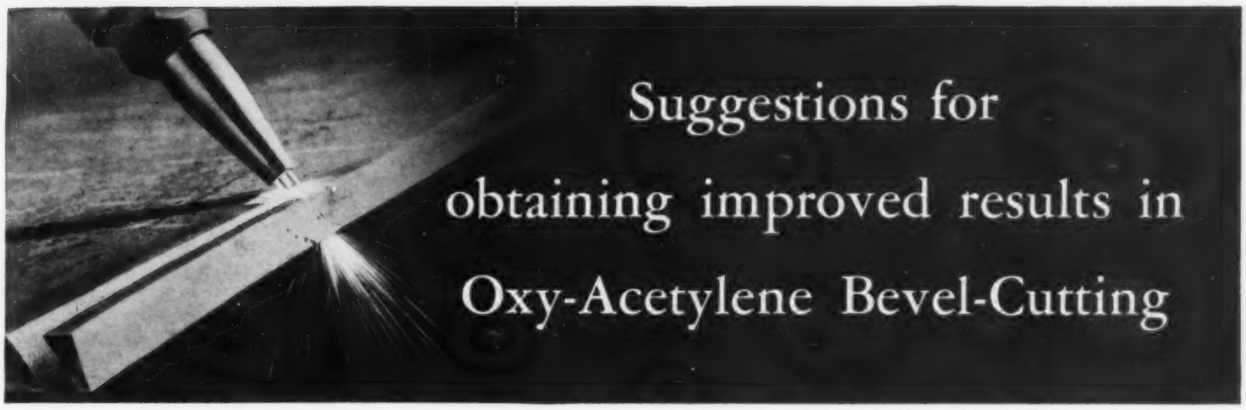
Shown dotted in Figure 2 are a contactor and resistor identified as "AS" and "$R_{as}$". By the use of suitable control circuits, contactor "AS" can be caused to automatically establish a shunting circuit across the motor armature when lowering out of the limit switch zone and to automatically remove the shunting connection when the switch resets.

The armature shunting connection causes dynamic braking torque to be developed with overhauling loads. Under this set-up, the lowering speeds do not become excessive by the time the limit switch resets. The change in speed at the point of throw-over is not very great and the transfer of connections takes place with a minimum of disturbance and without high strains and stresses in the hoist mechanism.

The shunting contactor may be mounted either on the hoist panel or as a separate unit out on the crane trolley. When located on the panel, the contactor is well protected and receives the same inspection and maintenance as the other parts of the control equipment. In addition to its automatic operation lowering and which is responsive to the position of the contacts in the limit switch, the contactor, when mounted as a part of the panel, can be used for establishing an armature shunting connection on the first one or two points of the master switch hoist. Such a connection will provide not only excellent speed regulation over a wide range of loads but also means for slowing the motor down, by dynamic braking, by notching the master switch handle back from its high speed points hoist to its slow speed points before returning the handle to its off position.

When the contactor is mounted out on the trolley, it is controlled from the voltage drop across the resistor used with the limit switch.

I believe this discussion covers the limit switch question which was asked by Mr. Angel.



# Suggestions for obtaining improved results in Oxy-Acetylene Bevel-Cutting

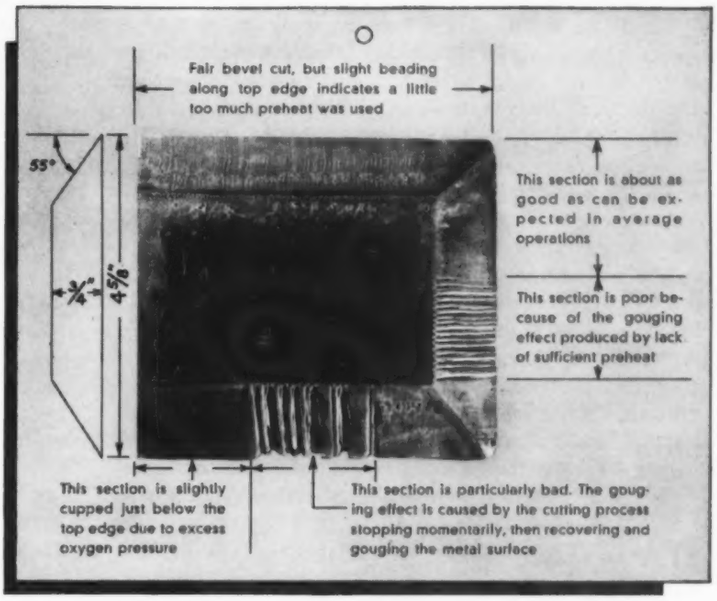
IN the preparation of plate edges by means of oxy-acetylene flame-beveling, accurate adjustment of the preheat flames—as well as correct cutting speeds and nozzle sizes is extremely important in obtaining uniformly good results. Illustrated at the right are some test bevel-cuts which show this better than words can describe. To help operators do consistently good work, large-size wall charts showing these test cuts are available from any Linde office, without charge.

## More Preheat Required

In many cases, poor bevel-cutting results are directly due to insufficient preheat. The reason that more preheat is required for bevel-cutting than for vertical-cutting is that, with the nozzle at an angle to the plate surface, the heat tends to "bounce off" and does not soak in to the same extent as when the preheat flames strike the plate at right angles. The flatter the angle, the greater the amount of preheat required.

## How to Increase the Preheat

For beveling angles up to 45 degrees, sufficient preheat can be obtained with standard nozzles by slightly "forcing" the preheat flames. For very shallow angles, it is sometimes necessary to provide supplementary preheat, either with a second blowpipe, or by first going over the line to be cut with the preheat flames of the cutting blowpipe.


Fair bevel cut, but slight beading along top edge indicates a little too much preheat was used
55°
¾"
4⅝"
This section is about as good as can be expected in average operations
This section is poor because of the gouging effect produced by lack of sufficient preheat
This section is slightly cupped just below the top edge due to excess oxygen pressure
This section is particularly bad. The gouging effect is caused by the cutting process stopping momentarily, then recovering and gouging the metal surface

*You can obtain a large-size (9 by 11 inches) wall chart of the above cutting guide from any Linde office, upon request. Ask for Form 5067.*

## Nozzle Size and Pressures

In bevel-cutting, the actual *depth* of the cut should be considered, rather than *plate thickness*, when selecting the nozzle, and when setting gas pressures and cutting speeds. The Instructions which came with your blowpipe will guide you in this. Duplicate copies of Instructions for apparatus supplied by Linde can be obtained from any Linde office.

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# BLAST FURNACE GAS

▲ THE heat units in all the gas from 200 blast furnaces in the United States are equivalent to more than 20 million tons of coal a year. This figure suggests both the magnitude and importance of putting blast furnace gas into condition for satisfactory utilization.

Blast furnace gas conditioning is accomplished fairly well from the performance standpoint, but not without considerable outlay in investments and operating expenses. Even so, if all the gas from all of our blast furnaces were fine-cleaned, the total cost, including capitalization, would be only about one-tenth of the total worth of the gas in terms of $3.00 coal.

One factor contributing to the costliness of blast furnace gas conditioning is the very large quantity of gas associated with a blast furnace unit. One large blast furnace produces volumetrically as much gas as 700 coke ovens, although only one-eighth that number of the latter are required to furnish the coke for the same blast furnace. In other words, we might say that a blast furnace produces about eight times as much gas volumetrically as its equivalent coke plant.

But there is another factor that contributes probably as heavily, if not more heavily, to the difficulty and the cost of blast furnace gas cleaning. This factor is the enormous differential in the sizes of contaminating stuff that exist in the gas and which, for the most part, must be removed in order to accomplish satisfactory conditioning.

### Nature and Origin of Gas Contamination

*Dust* — There are from 2 to 20 grains of more or less buoyant dust particles in every standard cu ft of gas leaving the top of a normally-working blast furnace. A fair average would be 10 grains per cu ft in the downcomer gas.

A sample of all the dust in the gas would have a size analysis approximately as shown in Figure 1. The largest of these particles average a little less than one-tenth of an inch in diameter, and the smallest class averages about five-millionths of an inch. Particles less than two-millionths of an inch have been observed under the microscope.

Perhaps some conception of the stupendous difference between the largest and the smallest dust particles can be had if we magnify the smallest to the size of a grain of cast-house sand, and the other class sizes in like proportion. Then the largest — the one-tenth inch particle — would reach 130 ft diameter, or about the noble proportions of the blast furnace itself. This comparison is shown in Figure 1. Other size classes would compare with other familiar objects.

Even with the above simile, it is difficult to establish a dimensional conception of a few millionths of an inch. Comparison with some familiar objects — if things that one cannot see except in large assemblies may be called "objects" — will perhaps be helpful. A particle of fog is at least 100 times as large as a particle of blast furnace

**Figure 1 — Size analysis and comparison of blast furnace dust.**

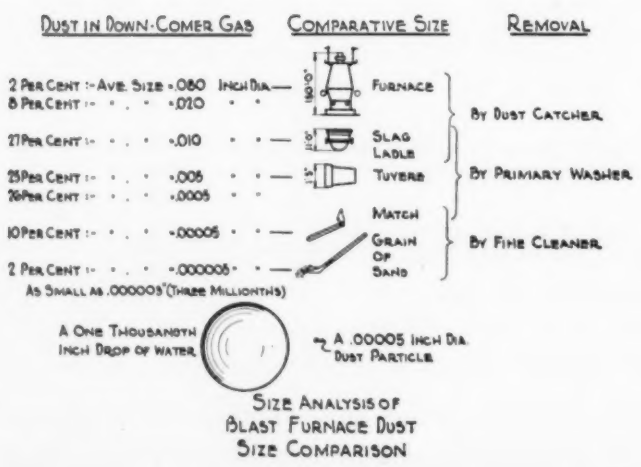
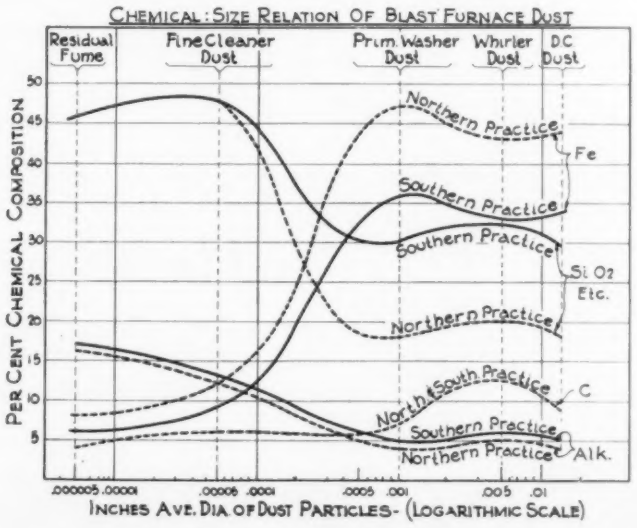

Dust in Down-Comer Gas
Comparative Size
Removal
2 Per Cent :- Ave. Size - .080 Inch Dia.
8 Per Cent :- . . . .020
27 Per Cent :- . . . .010
23 Per Cent :- . . . .005
26 Per Cent :- . . . .0005
10 Per Cent :- . . . .00005
2 Per Cent :- . . . .000005
As Small as .000005" (Three Millionths)
Furnace
Slag Ladle
Tuyere
Match
Grain of Sand
By Dust Catcher
By Primary Washer
By Fine Cleaner
A One Thousandth Inch Drop of Water
A .00005 Inch Dia. Dust Particle
Size Analysis of Blast Furnace Dust Size Comparison

**Figure 2 — Curves showing relation between size and chemical composition of blast furnace dust.**



# CONDITIONING

*By Owen R. Rice*

METALLURGICAL ENGINEER

**FREYN ENGINEERING CO.**

CHICAGO, ILLINOIS

***. . . . blast furnace gas conditioning, so important in the modern usage of the gas, has reached a high degree of performance . . . . this article summarizes the methods and results . . . .***

gas fume; a particle of pollen causing hay fever is 300 times as large. A particle of cigarette smoke is about comparable in size with some of the fume particles in blast furnace gas, but there are many of the latter that are smaller still.

Particles smaller than four-millionths of an inch will never settle out, even in perfectly still air, but are kept aloft by the bombardment of the air (or gas) molecules themselves, causing the so-called Brownian movement, and gravity has no effect on them. Many blast furnace gas fume particles are of this nature.

It is small wonder, therefore, that dealing with the dust in blast furnace gas is not a casual matter, and that it has not been found feasible to remove the dust in one simple process or in one apparatus. There is perhaps no industrial process that attempts to deal in one operation with material of such immense size variation. Even the blast furnace itself, whose digestive ability is to be greatly admired, pales at the prospect.

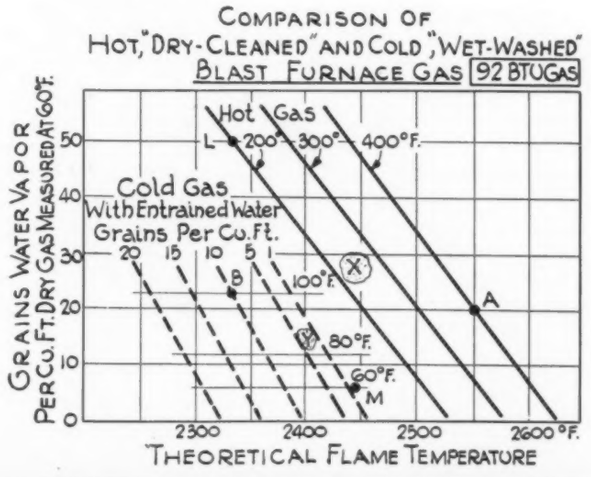
Rather, it is fairly surprising that it is possible to accomplish the cleaning of gas in the three customary steps — dry dust catching, primary washing, and fine cleaning. The approximate respective functions of these three phases are shown on the right of Figure 1.

It should not detract from a treatise on the topic at hand to inquire into the origin of this dust and fume in blast furnace gas. As every blast furnace operator knows, a large amount of the dust is the product of mechanical abrasion or attrition. In an accumulation of dust, one can readily identify familiar particles of coke, limestone and ore, obviously the result of rough handling of the ore in its mining, the stone in its quarrying, the coke in its transport and manipulation. Even if we should screen all the fines from the ore and stone, and blow all the dust from the coke, there would still be mechanically-made dust arising from within the furnace itself because of the restless movement and grinding of the materials in their progress down through the shaft. Or even if, in some unknown manner, this development of mechanically-made dust within the furnace could be forestalled, the gas in all likelihood would still be charged with particles rendering it unsatisfactory for many uses.

An attempt to secure clean gas by eliminating the contamination at the source is anything but promising. Much of the nuisance dust in blast furnace gas appears to consist of inevitable distillation products of the blast furnace itself. A size-chemical analysis of this duct, shown in Figure 2 and Table I, is quite interesting. We note that the larger size classes consist chiefly of iron, silica, and carbon, with a relatively small amount of alkalis, potash and soda, and of the acid radicals — chlorine, carbon dioxide, sulphur trioxide and hydroxide (OH). For convenience, alumina, lime and magnesia are lumped with the term silica.

As we get into the smaller size classes, we find the iron content approaching the vanishing point, the carbon content substantially reduced, and the "silica," alkalies and acid radicals all quite increased and defi-

**Figure 3 — Comparison of theoretical flame temperatures from hot, dry-cleaned and cold, wet-washed blast furnace gas.**



nitely predominating. These latter ingredients are, in all probability, distillation products of the blast furnace operation.

Potassium chloride boils at 1500 C, sodium chloride boils at 1413 C, potassium hydroxide boils at 1320 C, and sodium hydroxide boils at 1390 C.

Even amorphous silica, in the opal form, sublimes at 1750 C, which temperature is not out of line with that of the blast furnace tuyere zone; and we can identify graphitic carbon in the fine fumy dust, which substance we know is a product of chemical reaction, if not literally distillation, in the furnace. Even iron carbonyl, $Fe(CO)_5$, a liquid which boils at 103 C, could conceivably form under blast furnace conditions, boil off, decompose back to iron oxide and CO gas, and contribute to the diminishing but identifiable iron content of the fume sizes of gas dust.

In short, there is very fair evidence to the effect that much of the most troublesome dust in blast furnace gas, from the standpoint of the gas conditioning problem, consists of inevitable chemical and metallurgical distillation products from within the furnace itself, which no efforts at abatement of mechanically-made dust could reduce.

*Moisture* — In addition to the 2 to 20 grains of dust, blast furnace top gas contains between 7 and 50 grains of water vapor. A fair average is about 25 grains of water vapor per standard cu ft of dry gas in northern blast furnace practice. In the case of southern blast furnace practice, with the higher atmospheric temperature and humidity, and the presence of considerable combined water in some ores, a fair average is possibly about 34 grains $H_2O$ per cu ft of gas. (Incidentally, blast-drying might reduce this figure to about 30 grains per cu ft of gas.) Refer to Appendix A.

Water vapor in blast furnace top gas is an important contaminant. Its significance will be discussed later in this piece. Its source is the moisture and water-of-crystallization content of all materials charged to the furnace, including the blast. The water in the ore, stone and coke is driven off at relatively low temperatures, probably below 1200 F, at which temperature the water does not enter into chemical reaction but passes into the gas as vapor, and so remains when it leaves the furnace. The water vapor in the blast is probably all decomposed through contact with incandescent coke, to form hydrogen and carbon monoxide. Some of the hydrogen continues to exist in the gas as such; it shows up in almost every analysis of blast furnace gas. Most of the hydrogen, however, functions chemically as a reducing agent, and reappears in the top gas as water vapor. The extremes of possible water vapor content in top gas, as well as typical contents in both Northern and Southern practice, are shown, as to their derivation, in Appendix A.

*Summary of nature and origin of dust* — In summarizing the first two divisions of this piece, we find that the conditioning of blast furnace gas involves very large gas volumes, and has to deal with dust of enormous size variation, some portion of the dust consisting of extremely minute particles. Enough of the dust appears to originate from the digestive process of the blast furnace itself, so that preventive measures directed at abatement at the source would probably be of little practical value.

It will be noted that Figure 2 and Table I show comparisons between northern and southern practice. The data do not pretend to cover specific cases in either district, but are based on the averages of typical ones. It should be added that in general one of the greatest variations in the character of dust in specific cases lies in the content of alkalis and acid radicals. In several parts of the country there are ores, limestones or coals which contain percentages of alkali-bearing minerals such as orthoclase, albite, glauconite, and certain micas which add substantially to the percentages of potash and soda, chlorides, sulphates and hydrides in the dust. This is quite an important factor in connection with blast furnace gas conditioning and utilization, as subsequent discussion will set forth.

## Purposes of Blast Furnace Gas Conditioning

*Dust removal* — An obvious reason for removing the dust from blast furnace gas is to avoid the fouling of mains and consuming apparatus. Furthermore, it is almost invariably economical to recover the metallic values in the dust. This latter reason applies principally to the larger dust particles, for the smaller size classes do not, as a rule, contain metallics in sufficient percentage to justify their recovery.

Still, it is often with very good reason that we take measures to remove, or at least reduce, the fine dust particles. In gas-consuming apparatus which cannot be readily cleaned, such as small checker stoves and coke ovens, there will in time be sufficient accumulation of fine, fumy dust to interfere with free flow and ready heat transmission unless the gas is quite intensively cleaned. In gas engines, the concussion of the explosion may tend to bring about the agglomeration of even the most minute particles, which collect in a discouragingly short time as a precipitate on valves and pistons, so that valves fail to seat tightly, ignition parts are fouled, and cylinder liners become scored.

Another highly important reason for the so-called "fine cleaning" of blast furnace gas is to beneficiate its value as a combustible. The fine, microscopic fume particles are sometimes so numerous and so close together as actually to interfere with combustion. A so-called fumy gas, even though cleaned to 0.25 grains dust per cu ft, appears to contain something like 30 billion fume particles to the cu ft, and the average distance between them appears to be less than half a thousandth of an inch. These figures are speculative, but they are based on competent microscopic examination, and their general magnitude suggests why fumy gas burns poorly. In fact, it is a not unfamiliar phenomenon to have a fairly well-cleaned, but still fumy, gas fail utterly to ignite and burn in stoves and boilers. This phenomenon has been produced synthetically by injecting into a clear gas flame a thin stream of very finely pulverized salt. The flame could almost be extinguished.

*Water vapor reduction* — The presence of substantial amounts of water vapor in blast furnace top gas has attracted the attention of several generations of heat economists and combustion engineers. Water vapor is

an apparent liability because it adds to the quantity of combustion products, and so impairs the heating value of the gas. The quantity of water vapor in top gas is such that the dewpoint is about 110 F. Consequently, if the gas is cooled to say 90 F, about half of the water vapor is condensed, and there is an opportunity to get rid of it. Cooling the gas to 90 F is a possibility usually well within the scope of plant service water. Most blast furnace gas cleaning today is by the wet process, involving the copious application of water. The reduction of water vapor content through cooling has been held up as being one of the advantages of the wet-cleaning process. This claim has touched off vigorous controversy between wet-cleaning proponents and the believers in hot, dry gas. The writer will indulge in comment upon this controversy in later paragraphs. From the academic aspect, the wet-cleaning advocates seem to have lost the case, but from a practical standpoint, they certainly won the field.

### Required Degree of Cleanliness

*How clean is "clean"?* — We shall be using certain figures having to do with grains of dust per cu ft of gas. To those who are familiar with the manipulation of

**TABLE I**

**Typical Chemical and Size Analyses of Blast Furnace Dusts**

| | (a) Fe | $SiO_2$, $Al_2O_3$, CaO, MgO | C | (b) Alk. | (c) Acids |
|---|---|---|---|---|---|
| Top-gas dust | | | | | |
| (.010 in. average diameter) | | | | | |
| 100 per cent | | | | | |
| Northern practice | 44 | 18 | 10 | 4 | 5 |
| Southern practice | 34 | 30 | 10 | 5 | 6 |
| Dust catcher dust | | | | | |
| (.014 in. average diameter) | | | | | |
| 65.4 per cent | | | | | |
| Northern practice | 44 | 18 | 9 | 4 | 5 |
| Southern practice | 34 | 30 | 9 | 5 | 6 |
| Whirler or secondary dust catcher dust | | | | | |
| (.0046 in. average diameter) | | | | | |
| 20.5 per cent | | | | | |
| Northern practice | 43 | 20 | 13 | 5 | 5 |
| Southern practice | 33 | 32 | 13 | 6 | 6 |
| Primary washer sludge | | | | | |
| (.001 in. average diameter) | | | | | |
| 12.3 per cent | | | | | |
| Northern practice | 47 | 18 | 7 | 4 | 5 |
| Southern practice | 36 | 30 | 7 | 5 | 6 |
| Fine cleaner sludge | | | | | |
| (.000005 in. average diameter) | | | | | |
| 1.7 per cent | | | | | |
| Northern practice | 12 | 48 | 6 | 12 | 13 |
| Southern practice | 9 | 48 | 6 | 13 | 15 |
| Fume in "fine" gas | | | | | |
| (.000005 in. average diameter) | | | | | |
| 0.1 per cent | | | | | |
| Northern practice | 8 | 46 | 4 | 16 | 18 |
| Southern practice | 6 | 46 | 4 | 17 | 19 |

(a) Fe x 1.33 = $Fe_xO_y$ as probable average form in dust.
(b) $K_2O$ plus $Na_2O$
(c) $C_1$, $CO_2$, $SO_3$, OH

blast furnace gas, these figures have certain significance — as figures. They know, for example, that .20 grains is the usual measure for primary-cleaned gas, that .01 grain gas is good for small-checker stoves, and that .005 grain gas is unusually clean. However, one does not often encounter a finite conception of what clean gas is like, and one does occasionally hear some rather random expressions as, for instance, that "there is no use in cleaning the gas to such-and-such a figure because the air about the plant is not that clean." This is generally a misconception. Surveys of air contamination in the industrial districts of Chicago have indicated an average of .0004 grains of filterable material per cu ft of air. The highest reading showed .002 grains per cu ft. Tests in the center of the steel plants indicated about .001 grains per cu ft. In other words, .002 grain air is very dirty air, whereas .002 grain blast furnace gas is so clean as to be exceptional and only rarely encountered.

There is some divergence of opinion as to how clean the gas should be for use in stove checkers of various kinds, for old or modern boilers, for soaking pits, and for coke ovens. The convenient answer to this question is to fine-clean all the gas, and have done with it, regardless of the variety of its uses. Fine-cleaning specifications usually involve 0.010 or less grains dust per cu ft, water vapor content corresponding to 100 per cent saturation at about 80 F (11 grains per cu ft), and not over 1 or 2 grains of liquid entrained water. But the curve of installation and operation costs rises sharply upon breaking into the domain of fine cleaning, and there is precedent to show that a more conservative treatment of a considerable bulk of the gas is entirely reasonable, and renders it suitable and satisfactory for a substantial number of consumers.

*For boilers* — Boilers are usually not at their best with so-called raw or dust catcher gas. The sensible heat may be an advantage if the gas can be brought to the boilers before most of the temperature is lost by radiation. But a vast accumulation of clinker in the combustion chamber, the dust on tubes and in breeching, and a long, dusty flame are not regarded as in line with modern boiler practice.

However, an interesting demonstration has recently disclosed that under certain circumstances, so-called dust catcher gas can be used in boilers with substantial satisfaction. A new steam generating station having water-walls and continuous ash disposal, is said to be burning blast furnace gas directly as it comes from a secondary dust catcher, with apparent satisfaction and success. The dust in the gas is viewed in the same light and treated in precisely the same manner as the ash in powdered coal. In Appendix B, the writer sets forth some calculations indicating that for equivalent heat release, the quantity of ash in dust catcher gas may indeed be no greater in total quantity than the ash from powdered coal. It is intimated at the boiler plant above referred to that there is less fly ash from the stack when firing with blast furnace gas than with powdered coal. This may indicate that the blast furnace operation which serves this boiler is of the comparatively fume-free variety. If such is the case, it may be one of the circumstances contributing to the success of this interesting demonstration of the use of dust catcher gas in a modern boiler.

Perhaps the worst gas for boilers is the so-called primary gas of ten to twenty years ago — the .25 grain gas, cold, moisture-saturated and sloppy, with anywhere from 5 to 50 grains of entrained liquid water.

In a few cases, boilers have been served the luxurious and costly diet of fine-cleaned gas. But within recent years, a number of large, modern steam generator plants have utilized with entire satisfaction an improved quality of primary gas. By this is meant under 0.15 grains of dust per cu ft, saturated at about 80 F, substantially free of entrained water.

Particularly beneficial in this improved primary gas is the elimination of entrained water. In one instance the output of a 10,000 boiler hp plant was increased by more than 6 per cent, firing the same quantity of gas, after changing over from conventional primary-washed gas to what has been designated above as improved primary gas. The removal of entrained water is particularly impressive in this instance.

Summing up the topic of the proper degree of conditioning gas for boilers, it may be said that primary gas, once the bane of the boiler house, has now been improved to the extent of being an efficient and satisfactory boiler fuel. A dust content of 0.10 grains maximum per cu ft, in conjunction with the elimination of entrained water, is an adequate specification for boiler gas.

There is, however, at least one instance of the apparently satisfactory use of so-called dust catcher gas in a modern boiler, and it may be added that there are a number of projects afoot which are considering this same procedure.

*For hot blast stoves* — There is considerable divergence in practice, and still more divergence of opinion, as to how clean gas should be for stoves having checkers of such-and-such a size or design. Most operators who have installed small or filler-type checkers have gone to fine-cleaned gas, nominally .01 grains of dust per cu ft. There are some instances, possibly more than a few, wherein stove remodeling projects have been held in abeyance because of the apparent magnitude of the coordinate gas cleaning program.

There is a feeling in some quarters that entrained water in the gas contributes greatly to the fouling of stove checkers with dust; that if entrained water is eliminated, a dust content of say .07 grains per cu ft is satisfactory for checkers having as small as 2½ in. openings; and that for such checkers — although they may come under the classification of "small checkers" — it is not necessary to assume the high cost of fine gas cleaning.

Another qualifying circumstance is the demonstration that stoves can be washed. In one instance, probably the first of its kind but not the last, an operator was happy to be granted a stove-improvement appropriation involving the placing of inserts in existing checkers. It seemed rather obvious that such a program should have included some attention to gas conditioning, but this was not granted, and the operator was left with the necessity of serving his new stove checkers with an indifferent quality of primary-washed gas. In an almost breathlessly short time, his stoves were

plugged up, the furnace was faced with shut-down, and the operator was in a dilemma of considerable personal magnitude. With admirable courage, he did what every young blast furnace learner is taught must never, never be done — he got his stove checker brick wet. He turned water into the tops of his stoves and flushed the checkers from top to bottom. Out came the dirt, and the proceeding was a grand success. The stoves suffered no damage whatsoever, and have run for many years since. There will not be many blast furnace operators voluntarily place themselves on record as accepting a rather speculative quality of gas for their new stoves, resting serenely on an apparent assurance that in the event of trouble, recourse can be had to the laundry. However, the stove-washing circumstance may act as a sort of mental back-log for those who feel that too much emphasis is placed upon the necessity for fine-cleaning stove gas; or for those who pioneer in new schemes of gas cleaning and seek some medium of resort in case of trouble. Mental back-logs often crystallize into opinions, and opinions lead to actions. To this extent, the stove-washing circumstance seems to have a bearing on the aspects of blast furnace gas conditioning, title of this piece, and consequently the writer feels justified in introducing it.

Some years ago there appeared, to the astonishment of almost everyone concerned, another circumstance which may have had a demoralizing influence upon the attempt to peg the requisite degree of cleanliness for stove gas. It was about 1929 that fine-cleaned gas was first applied to blast furnace stoves. Since that time, there has come to light one instance after another, in steady procession, recording damage to upper checkers in varying degrees of seriousness, at stoves fired with fine-cleaned gas. By 1938 this situation was so widespread that a recognized authority in the United States blast furnace refractory field went on record with the statement that practically all hot blast stoves operating up to that time under modern procedure of gas cleaning, showed evidence of fusion, slagging and shrinkage of top checkers and bonded brickwork. It seems to be established virtually beyond question that this fusion, slagging and shrinkage of brickwork is caused by free, unsatisfied alkalis penetrating the brick structure and causing mineralogical changes at certain critical temperatures.

The cleaner the gas, the worse this condition appeared to be, and it was not long before it was realized that the cleaner the gas, the higher was the percentage of free alkalis in the dust that did remain in the gas, precisely as has been indicated in an early part of this treatise. It did not seem to matter greatly whether the gas was cleaned to .05 or .005 grains dust per cu ft. The latter made up in intensity of destructive properties what it may have lacked in bulk.

The identical phenomenon has almost never occurred in connection with stoves fired with any but fine-cleaned gas, because only in the latter case is there present in the dust free alkali which cannot be satisfied by acid minerals also in the dust. True, the combine would form clinker and slaggy deposits in stove brickwork, but rarely did stove brickwork itself melt and shrink away, until fine-cleaned gas was used. Those who suggested that fine-cleaned gas might burn with a hotter and therefore more destructive flame than partly-cleaned gas, were asked to recall that many stoves were run for decades on hot raw gas which, at least at intervals, was clear and clean enough to develop exceedingly high flame temperatures by reason of its preheat.

This wave of stove damage accompanying the use of fine-cleaned gas was adopted for argument by both the opponents and the proponents of fine-cleaning. The former viewed with alarm what they called the ill-considered stampede toward fine-cleaning, while the latter pointed with pride, and said that it just went to show, as they had maintained all along, that gas just could not be too clean; and they are probably right, but only academically right, for it is probably impractical to clean blast furnace gas so thoroughly as to remove all the harmful alkalis.

This matter of requisite stove gas cleanliness is not settled even now, so that this present treatise cannot even pretend more of an answer than has already been given. But that is no reason to leave suspended in air the rather shocking account of the hot blast stoves fired with fine-cleaned gas. Even though this is not a treatise on stoves, any reader who has penetrated this far must have a breadth of mind that reaches forth beyond mere gas cleaning, even into the sphere of stoves, and so may inquire as to what has been done about it.

So-called super-duty or super-refractory brick made what seems to be its first appearance in stove construction in about October, 1936. Since then it has been increasingly adopted. It is said to have a somewhat higher fusion point than first quality firebrick, and much superior resistance to spalling. But more than this, it appears to have the property of protecting against, or at least retarding, alkali penetration on account of the formation of an interface of mullite needles ($3Al_2O_3SiO_2$), which form a resistant layer. Almost all stoves built in the last three years and dedicated to the use of fine-cleaned gas, specify super-duty brick for the portions most vulnerable to alkali penetration.

Coupled to the employment of super-duty brick has been the adoption of controlled limitation of flame temperatures playing on the top checkers and dome structure. This latter measure has been made possible through recent improvements both in gas burners and in pyrometer technique.

Stoves equipped with super-duty brick and operated with regulated dome temperatures have been in run long enough to give strong indication that the detrimental effects of alkali fume in fine-cleaned gas have been at least greatly curbed.

*For soaking pits* — Soaking pits fired with blast furnace gas have received a variety of diet. In some instances it is fine-cleaned gas (0.01 grains). But in one exemplary instance, the pits are fired with ordinary primary-washed gas which passes through a considerable length of main and arrives in a condition comparable to what has been designated previously as "improved primary gas" — under 0.10 grains dust, and dry. More than four years of operation on this basis seems to indicate that "improved primary gas" can be used satisfactorily at soaking pits.

*For coke ovens* — Ever since blast furnace gas was first applied to coke ovens, the hypothesis has been set up that no cleaning could be too fine. There was not so

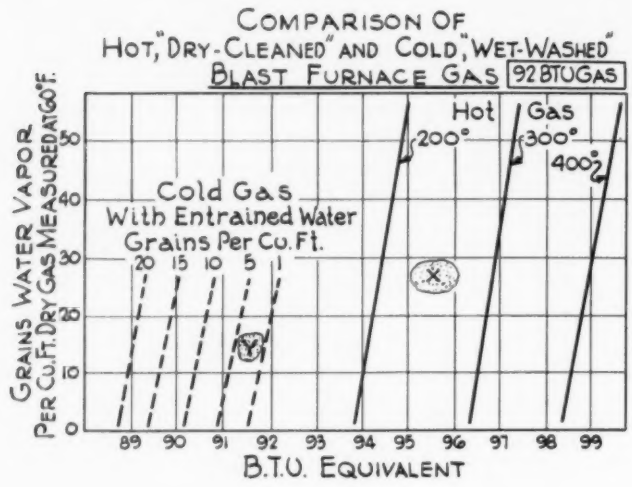
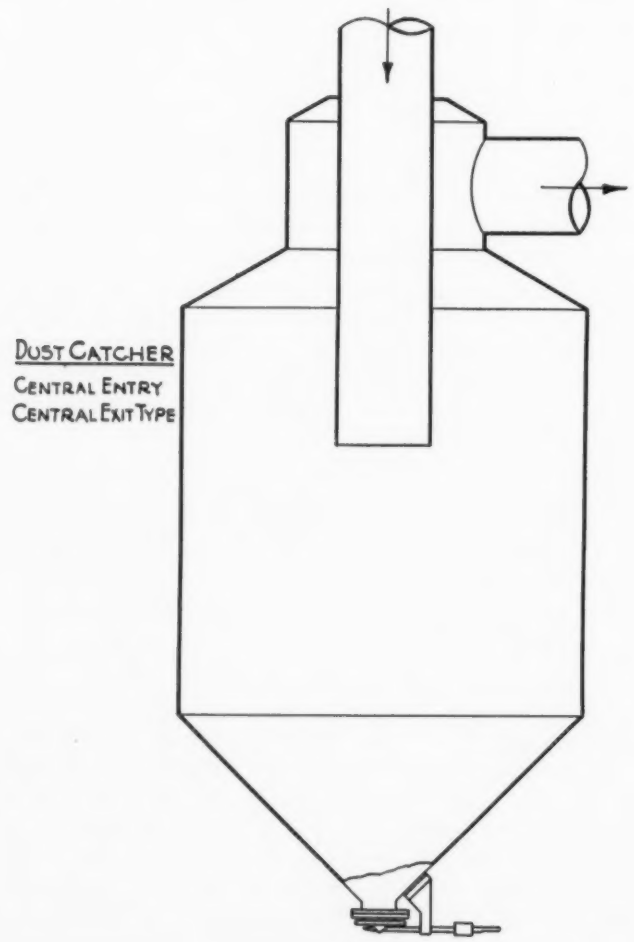



**Figure 4 — Comparison of Btu equivalent of hot, dry-cleaned and cold, wet-washed blast furnace gas.**

**Figure 5 — Sketch showing general arrangement of dust catcher (central entry, central exit type).**




long ago a demonstration covering a five or six months period in which a battery of ovens was continuously fired with gas containing about 0.05 grains dust. This did not prove to be satisfactory and was abandoned. We are inclined to leave unmolested the specification that fine-cleaned gas, .01 grains per cu ft or better, should be used at coke ovens.

*For gas engines* — The desirability of highly cleaned gas for gas engines is probably incontestable. For years they were served with so-called fine-cleaned gas of a former day — the 0.03 grain gas from drum-type scrubbers or wet fans, and fouling of valves and scoring of cylinder liners were well known sources of trouble. More recently, intensive fine gas cleaning of the "double-O" variety has been most helpful in reducing gas engine maintenance.

*Summary* — Summing up this matter of gas cleanliness with relation to gas utilization, it seems to be quite definitely established that for coke ovens and gas engines, the dust content should be reduced to .01 grains or less. For modern, small-checker stoves, the general practice is to clean the gas to about .015 grains, although divergent opinions maintain, on the one hand, that this is unnecessarily clean, and, on the other, that it is not clean enough. Primary gas cleaned to .10 grains or less and free from entrained water, appears to be satisfactory for boilers and soaking pits and similar steel works uses. There is also one instance of the apparently successful use of secondary dust catcher quality gas at boilers, in which the dust is viewed in the same light and treated in the same manner as the fly-ash from powdered coal firing. This latter practice is commanding attention in connection with a number of new boiler projects.

### The Wet-Dry Controversy

Since virtually the beginnings of blast furnace gas conditioning, there have been two distinct and controversial schools of thought, one adhering to the principle of hot-dry cleaning, the other supporting the principle of cold-wet cleaning. Considerable sums and substantial quantities of eloquence have been expended upon a controversy covering at least thirty years. This was the argument:

Said the dry-cleaning proponents: Behold the 400 degrees of sensible heat in the top-gas of a blast furnace. Many valuable Btu reside there. What if there is some water vapor in the gas, it constitutes a relatively small debit, if any, provided you don't drown the furnace stock with water. Furthermore, you will find that this hot gas is far more readily ignitible and combustible than cold wet gas. And another thing, if you clean gas by a dry method, you collect all the dust in the dry state — no contamination of streams and lakes, no sludge disposal plant.

Replied the wet-cleaning advocates: Don't be too sure about the net thermal benefits of hot gas. First of all, we question your 400 F figure for top-gas as a temperature at which the gas would reach the consumer after substantial travel in mains. Secondly, we are going to put as much water on the stock as we think is best for the furnace operation, and we will not subordinate this to the requirements of gas cleaning and

utilization. Thirdly, as to collecting all the dust in the dry state: we do not find a more irritating nuisance around a blast furnace plant than your dry, hot, fine dust. It lowers the standard of working conditions and safety. It is virtually unusable in its existing form, and it has to be handled and processed before it can be reclaimed. Besides, the wet-cleaning advocate asked the dry-cleaning proponent, just how clean can you get the gas for how much money?

The last question perhaps has done more than any other to "stump the experts." As a matter of fact, it does not seem possible to dry-clean blast furnace gas quite clean enough for modern uses, at a cost which will be compensated by a somewhat academic thermal economy.

Figures 3 and 4 set forth a condensed diagnosis of the hot-dry vs. cold-wet gas conditioning controversy. The matter is viewed from two standpoints, viz., flame temperature and net thermal value. The gas under consideration has a thermal value of 92 Btu per cu ft, dry, and at 60 F and 30 in. Hg.

In Figure 3, the full lines show the theoretical flame temperatures that obtain to the combustion of hot cleaned gas of several temperatures, and accompanied by various amounts of water vapor. The broken lines show the theoretical flame temperatures that obtain to the burning of cold washed gas saturated with water vapor over a scale of typical temperatures, and accompanied by more or less liquid water.

Depending upon what one chooses to assume as to "existing conditions," one can set up a case favorable to either side of the controversy; a good example of making figures show what you want them to show. For example, points A and B represent the situation as the dry-cleaning advocate would present the case. He exhibits point A and claims 400 F of temperature and concedes only 20 grains of water vapor content for hot, clean gas. Such a gas would yield about 2550 F theoretical flame temperature. He contrasts this with point B, which he says represents cold washed gas, viz., 100 F and saturated with 23 grains of water vapor and accompanied with 10 grains of liquid water. About 2330 F is the best one can expect in the way of flame temperature from such gas. The dry-cleaning advocate chalks up a net score of 220 F for his side.

The wet-cleaning proponent exhibits points L and M. He claims hot gas rarely reaches the consumer with more than 200 F of temperature, and he has known top-gas to be accompanied by 50 grains of water vapor. Such gas (point L) will yield only 2330 F theoretical flame temperature. He claims, on the other hand, that cold washed gas can be cooled to 60 F at which temperature it is accompanied by only 6 grains of water vapor; and as for entrained water, — "Why, that drip is just on the walls of the main; the gas is dry as a bone; no entrainment!" Such gas (point M) shows 2450 F flame temperature. He claims cold washed gas is better than hot cleaned gas by 120 F in flame temperature.

An impartial judge would probably say that region X fairly represents the general run of hot gas is at can be brought to the consumer, viz., about 250 F and accompanied by 25 to 30 grains of water vapor; flame temperature 2440 F. He would say that region Y fairly represents the general possibilities for wet washed gas, between 80 and 90 F saturated, and therefore accompanied by 12 to 16 grains of water vapor, and entrained liquid water between 1 and 5 grains per cu ft. Such gas could claim a theoretical flame temperature of 2400 F. He might render a verdict of 40 F in favor of dry cleaned gas; a technical victory, perhaps, but not overly impressive.

The situation may also be viewed on the basis, Figure 4, of thermal comparison or "Btu equivalent." Consider a standard gas having a heat value of 92 Btu per cu ft, having no water vapor or entrained water, and existing at 60 F. It is burned in a heat-absorbing machine, as, for example, a hot blast stove, of such capacity that the products of combustion go to the stack at 350 F. The theoretical flame temperature is 2465 F. Under the above conditions, it leaves a certain amount of heat, viz., 82.1 Btu in the stove. This standard gas is said to have a "Btu equivalent" of 92.

Other gases of the same thermal value per standard cu ft have certain thermal credits and debits attaching to them by reason of their actual temperature and by reason of water vapor and entrained liquid water accompanying them. Such gases, burned in the same heat-absorbing machine, will leave different amounts of heat in the machine. For example, a gas at 250 F, accompanied by 28 or 30 grains of water vapor, will leave 85.4 Btu in the stove. The Btu equivalent of this gas is $92 \times 85.4 \div 82.1$ or 95.5.

In like manner, if the gas is cold and saturated, and wet with liquid entrainment, it might have a Btu equivalent of 91.5. This gives the dry cleaning advocate a benefit of about 4 per cent in theoretical heat economy over the wet-washing school.

This general manner of diagnosing the picture sustained the advocates of dry cleaning for a long time. Indeed the concept even now is by no means dead; rather, perhaps it merely awaits the possible coming of a dry cleaning scheme which will attain the same quality of dust removal as wet washing, at a comparable cost.

In the early days of cold, wet, "sloppy" primary gas, the wet-cleaning advocate had often to listen with embarrassment and some confusion to the complaints of his boiler men and stove tenders who could not make the gas light off and burn effectively, and who frequently and audibly yearned for the good old days of hot, dust-catcher gas. That situation has faded since the advent of marked improvements in wet cleaning. But, consciously or unconsciously, the curse of "sloppy" gas for a long time was probably one of the retarding influences against the wider adoption of gas conditioning.

### Dry Cleaning Methods and Apparatus

In this category are found dust catchers, whirlers, electrical precipitators of the dry type, and bag filters. They are named in the order of the degree to which they accomplish the removal of dust.

*Dust catchers* — Dust catchers of all sorts of shapes, sizes and styles mark the history of dust collecting. The dust catcher is fundamentally a settling chamber. Dust is dropped out of the gas by reducing the velocity of flow. So long as the dust catcher adheres to this princi-

ple, it performs quite satisfactorily within its field, and functions with a minimum of trouble.

There have been frequent attempts to enhance the effectiveness of the dust catcher by bringing the gas into it tangentially in the hope of employing centrifugal force. The dust catcher is a device of essentially large diameter and dedicated to low velocities. Centrifugal force is at its best with small diameters and high velocity. Consequently, the benefits secured in a tangential type dust catcher are probably of rather moderate degree.

A recent type of dust catcher is shown in Figure 5. It has a single large entry pipe in the top, leading down part way inside the chamber portion, and a concentric, header-like offtake, also in the top. This design makes full use of the available volume and areas for slowing down velocity. There is a minimum opportunity for short-cutting from inlet to outlet.

A good dust catcher may clean the gas to about 3 grains dust per cu ft.

*Whirlers* — Secondary dust catchers of designs which simply repeat the principle of the primary dust catcher are often conspicuous for their nuisance value. They accumulate just enough dust to require attention. If attention is postponed (a temptation stimulated by the meager returns), the small accumulation of dust cools down, becomes wet with condensed moisture, and sets into a defiant mass.

There are highly effective whirlers based on the skilful application of centrifugal force. They are fundamentally of small diameter, and usually of considerable vertical dimension. They are especially useful for backing up an inadequate primary dust catcher, or for helping out an ensuing primary washer which may be of a type that is prone to plug up unless the dust content of the entering gas is substantially reduced.

A good whirler will clean the gas to a dust content of about 2.0 grains per cu ft. This is the kind of gas that might be found satisfactory in the modern steam generator equipped to handle the dust in the same manner as powdered coal fly-ash.

Against the use of whirlers are the following factors: Applications of whirling or centrifuging to blast furnace dust collecting with sufficient vigor to yield substantial effect, are marked almost inevitably by an annoying amount of wear and maintenance cost. The dust from a whirler is even more difficult to handle and wet down than is that from a dust catcher. A reliable type of primary washer does not require the protection of a whirler ahead of it. Moreover, if this size category of dust is not sent to the washer, the latter is left with the duty of extracting a size class of dust which, in the washer discharge water, consists almost entirely of slimes. Subsequent sludge disposal is hampered because of the difficulty of filtering these slimes without the accompaniment of some "sandy" material to preserve the porosity of the filter cake.

If a good dust catcher exists, then a supplementary whirler seems to be justified only at a plant committed to hot gas utilization.

*Dry-type precipitators* — About twenty years ago, the dry-type electrical precipitator commanded considerable attention in the blast furnace field. Several of the installations made about that time have functioned acceptably, as is evidenced by the fact that they are still in operation. There have been exceedingly few recent installations of dry precipitators at blast furnaces.

The ultimate degree of clean-up of which the dry electrical precipitator appears to be capable, even upon double pass of the gas through a secondary unit, seems to be to about .15 grains of dust per cu ft. This and even better cleanliness can be secured today in wet primary washers costing less money than required for a dry precipitator installation. Of course, the matter of water availability has been a critical item in some instances; and it is also perfectly true that the ability of wet primary washers to turn out .15 grain gas was by no means clearly demonstrated twenty years ago.

The dry-type precipitator shows little indication as yet of occupying a position of general significance in the blast furnace gas cleaning field. It does not clean well enough for the money.

*Bag house* — The bag filter system is rarely, if ever, used in this country for cleaning blast furnace gas. It would not receive mention here were it not that it is the one dry-cleaning system that can and does clean the gas to as high a degree as could possibly be asked for by any consumer. A bag filter system will take gas containing 2 grains of dust per cu ft and clean it to .002 grains, a performance which is 99.9 per cent efficient. This degree of clean-up appears to exceed the present practical requirements of blast furnace gas consuming apparatus.

The bag house is a costly and cumbersome institution. Being a regenerative process, the installed capacity has to be considerably larger than the operating rating, so that the physical dimensions and the necessary valving provisions approach the grotesque. Control is difficult and fine-haired. The gas must be pre-cooled sufficiently to prevent injuring the bags, yet not so much as to permit moisture condensation, which is calamitous. One instance of failure to keep temperatures at specification, and the entire set of bags is apt to be ruined. The collected dust must be shaken periodically from the bags or "stockings," a procedure that usually establishes highly offensive pollution of the surrounding atmosphere. The recovered dust itself is exceedingly difficult to handle, and again becomes offensive wherever and whenever an attempt is made to work it or dispose of it. No concession as to the degree of cleanliness required of the bag house system has any effect in mitigating the objectionable features that obtain to it. The system is employed in Germany.

### Primary Wet Cleaning

*History* — In a 1904 issue of The Iron Age, we find an article describing the Zschocke tower as a device used in Europe for cleaning gas by means of water sprays in a vertical tank. A year later (1905), the same publication found it timely to announce gas cleaning progress in this country by referring to stationary scrubbers consisting of vertical chambers containing sprays of water, and sometimes provided at intervals with some type of porous filter. This may not be the earliest reference to the use of water for cleaning blast furnace gas in this country, but it is not far from being so. Professor Hofman, in his lectures of 1900 at the Massachusetts Institute of Technology, does not men-

tion such a procedure, nor does the reproduced plan of the Duquesne blast furnace plant, accompanying Professor Hofman's lectures, show any gas cleaning equipment beyond the dust catchers. In 1902, Thomas D. West published his book "Metallurgy of Cast Iron." He describes the top-gas from a blast furnace as going direct to boilers and stoves. He reproduces a photograph of a "modern blast furnace," in which the only visible gas cleaning apparatus is a very small dust catcher.

Hence, the origin of wet gas cleaning in this country seems to have been about 1904 or 1905. By 1913, the process commanded such extensive attention that at the February, 1914, meeting of the American Institute of Mining Engineers, A. N. Diehl delivered a paper on the relative merits of dry and wet gas cleaning, and precipitated the controversy on that subject which has existed ever since. In 1917, J. E. Johnson, Jr., described at least eight different kinds of wet gas scrubbers of the day, but he seems, unaccountably, to have overlooked two of the most widely used types, namely, the Steinbart tower with its rotating suspended axial nozzle, and the Brassert-Bacon static washer with its solid cone sprays and wood hurdles.

We came down to the nineteen-thirties with the primary gas washing field divided between two general types, the mechanical washer and the static washer. The former was represented by Feld and McKee, and involved a series of rotating cones on a vertical shaft for developing a mechanically-induced spray of water through which the gas passes. The static type of washer was represented chiefly by those which used stationary spray nozzles in conjunction with hurdles, either of ceramic tiles or of wood slats. The dust-removing principle upon which these latter operated was that of bringing the gas in contact with extended wetted surfaces.

The general class of clean-up obtained from these washers was to .25 grains of dust per cu ft of gas, although one will encounter many stout claims of much better performance. The mechanical washers sometimes did a slightly better job of cleaning than the static washers, but considerable horsepower was required to run them, and they were characterized by an annoying amount of maintenance cost and offage time.

About 25 gal of water were usually required for each 1000 cu ft of gas handled.

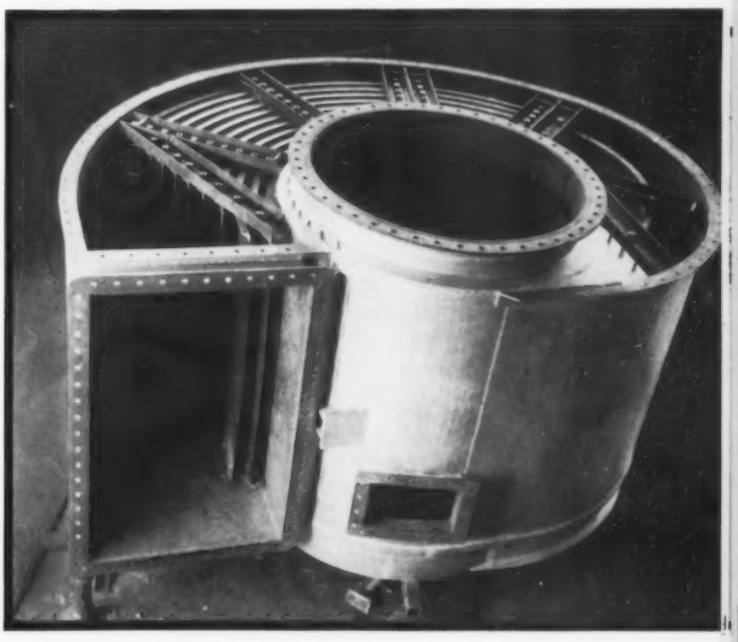
The greater portion of the gas from these primary washers went directly to stoves and boilers without further treatment. Viewed in the present day, the gas quality was not very good. In fact, there are many boiler operators who will rise to say that it was very bad. The common objectionable characteristic was entrained water, making a sloppy gas. Slimy mud collected in mains and dripped from downlegs. It dried and baked in burners, and plastered onto boiler tubes; and in comparatively small boiler furnaces, the gas sometimes burned feebly and showed unburned CO simultaneously with excess oxygen in the breeching, a condition both wasteful and hazardous. The behavior of such gas in stoves was not quite so objectionable. The extended combustion chamber volume and the hot brick walls promoted complete combustion, and a dust content of .25 instead of 2 or 3 grains per cu ft constituted a substantial relief from the copious clinker deposit in stoves which had previously used dust catcher gas. It was stove practice that perpetuated and promoted the use of these primary washers. In many cases the boilers, after a struggle, reverted to dust catcher gas, leaving the washers to handle only the 30 or 40 per cent used by the stoves.

*Improvements in primary gas cleaning* — After the above dubious eulogy of the time-honored primary washer, the question arises as to whether there have not been some attempts to improve the performance of apparatus which fundamentally has yielded results of comparatively indifferent character. Such efforts have indeed been made, some of them with considerable success. They have involved the incorporation of new elements, either as a new apparatus or as additions to existing units.

*Moisture eliminators* — Various devices for removing the slop from primary gas have been proposed and tried. Some of them did the work, but perished in the attempt by plugging up. Others could be kept open only by frequent applications of flushing water, which practically neutralized their function. Early in 1934, the writer's company installed the first rubber-lined cyclone moisture eliminator. It consisted of a group of parallel, concentric gas passages, relatively narrow and relatively high, whose walls consisted of steel plates coated on both sides with vulcanized rubber. Figure 6 shows the construction of a cyclone eliminator with cover plates removed.

This device is installed either on the gas main after a washer as shown in Figure 7, or in the top of a primary washer as shown in Figure 8. It is not only an excellent moisture remover, but it functions also as quite an

**Figure 6 — Cyclone gas cleaner and moisture eliminator, with cover plates removed to show construction.**



effective cleaner, being capable of removing between 30 and 50 per cent of the dust in the primary gas.

There are several reasons for employing rubber in these cyclone eliminators. Rubber is of course non-corrosive and it resists abrasive wear. Moreover, deposits of blast furnace gas dust with their familiar hydraulic setting tendency, do not cling as tenaciously to rubber as they do to some other surfaces, such as metal. But a very important reason for using rubber is the ease of completely wetting it with comparatively little volume of water.

The essential idea of the cyclone cleaner is to have continuous, circumferential flow of gas, not interrupted or distorted by sprays or anything else, during which flow the dust particles can be acted on by forces which move them onto wet surfaces. Although there is enough entrained water in primary-washed gas to constitute a nuisance if it is not taken out, it is not present in great profusion like a spray. Consequently, it is necessary to have a surface that is easily and completely wettable with comparatively little water. Rubber meets this requirement.

Since their introduction in 1934, these rubber-lined cyclone eliminators and gas cleaners have been installed at twenty-seven blast furnaces, and have a summated rated capacity of almost three million cu ft of gas per min. This device has been outstanding as a means for

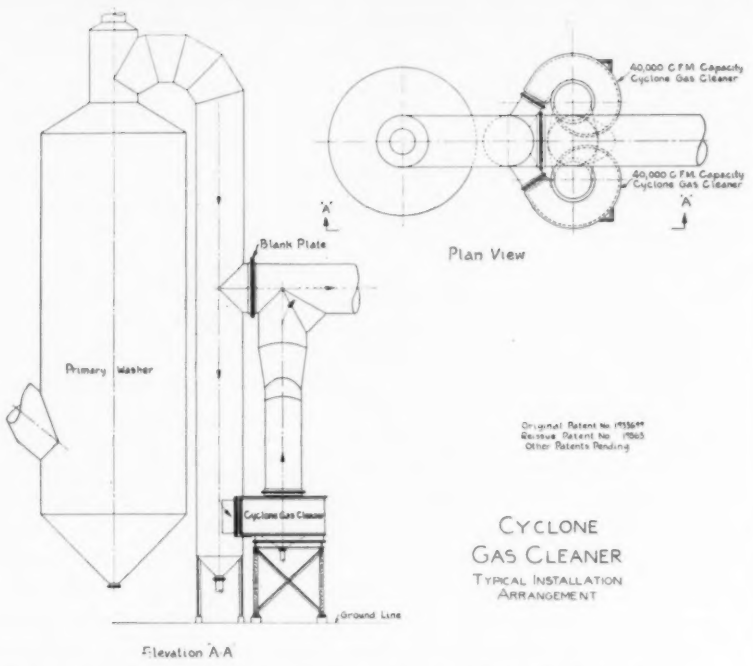
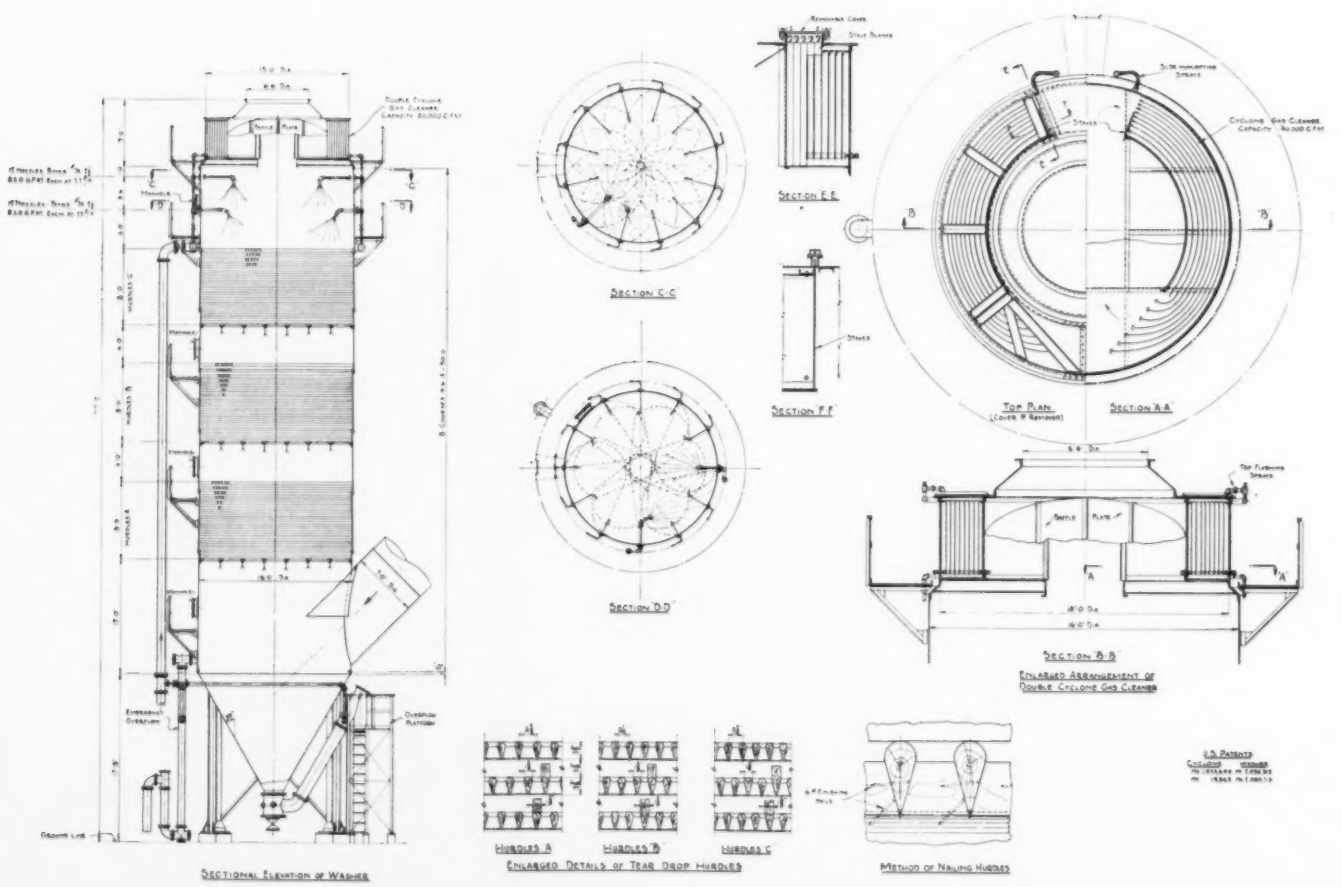



**Figure 7 — General arrangement showing installation of cyclone after the washer.**

**Figure 8 — General arrangement showing installation of cyclone in washer top.**



"sweetening" the performance of primary washers of all sorts, mechanical and static, tile washers, and wood hurdle washers. The function of this device is summed up by one operator, who remarked of the cyclone that "it certainly takes the curse off of primary-washed gas."

A static washer with tear-drop-shaped wood hurdles and surmounted by a rubber cyclone eliminator, as shown in Figure 8, is capable of turning out a gas containing .10 to .15 grains dust per cu ft, and virtually free of entrained water. Such gas is satisfactory for use in stoves having 3 in. checkers or larger, and it has demonstrated itself favorably in numerous boiler plants. This kind of improved primary gas is particularly suitable for subsequent treatment in electrical precipitators. This topic will be dealt with further under the discussion of fine gas cleaning. However, it may be stated here that precipitators are quite sensitive to the quality of the incoming gas, the capacity of the precipitator increasing and its general behavior improving if the incoming gas contains .10 to .15 grains of dust rather than .25 grains.

To those who are closely associated with the art of blast furnace gas cleaning, it has become a sort of axiom that you cannot effect very much improvement in cleaning by merely repeating or extending what you have done before. In order to materially improve the degree of gas cleaning, one must improve the method, not merely extend it.

All wet gas cleaning is based upon the premise that the dust cannot be removed from the gas unless the particles are wetted. Although the intelligent realization of the difficulty of accomplishing this fact with respect to the very fine dust particles is becoming more general, one still encounters the contented feeling that all that is necessary is to squirt in enough water and that, somehow, the gas will come clean. It just does not work out that way. Some of the corollary principles for wetting fine dust particles employed in modern primary washers, are:

1. Subdivision of the gas into small streams.
2. Turbulence of flow of the gas streams.
3. Contact of the gas with extended wetted areas.
4. Wetting by water vapor condensation.

There are to be found a considerable variety of new type primary washers for blast furnace gas. Among these are the Peabody washer, the Freyn ball washer, and the Freyn gas conditioner.

*Peabody washer* — The Peabody washer emphasizes principles 1 and 2 mentioned before, namely, sub-division of the gas into small streams and turbulence of flow.

The Peabody washer element or plate is in a measure a "secondary" primary scrubbing unit, for the reason that it is not adapted to receive raw dust-catcher gas directly, and, consequently, should be preceded by an effective scalping stage to remove the bulk of heavy dust. This preliminary stage can be an existing primary washer in which the former scrubbing elements or stages may have been somewhat abbreviated. In several instances, for example, the Peabody elements have been installed in the upper part of a Feld washer from which one or more cone stages have been removed.

The Peabody element is shown in Figure 9. It consists of a horizontal plate of stainless steel extending

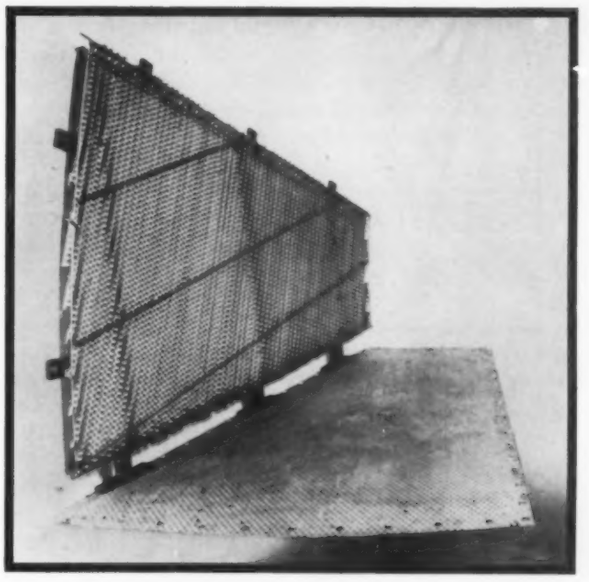


**Figure 9 — This washer element is a perforated horizontal plate of stainless steel which extends across the entire area of the washer tank.**

across the entire area of the washer tank, the plate being perforated with small holes approximately ¼ in. diameter. The plate is fabricated in pie-shaped segments, between which are radial troughs which conduct excess water to the periphery of the washer tank. A fraction of an inch above each perforated hole in the plate is a small impingement baffle.

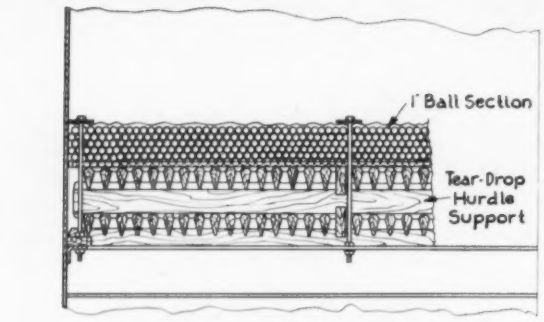
Upwardly-directed sprays apply water to the underside of the perforated plate, and the upwardly-moving gas, passing through the perforated holes, carries some water along with it. Gas and water impinge upon the small metal baffle plates mounted closely above each hole.

Several stages of Peabody elements or plates are sometimes applied in series in a washer.

It will be evident from the description that subdivision of the gas flow into small streams is carried to a very high degree in the Peabody device. The turbulence and the intimacy and violence of gas and water contact may readily be visualized. Cleaning to .05 grains per cu ft with gas from basic iron operation is said to be reliably demonstrated.

The pressure drop through washers equipped with Peabody elements appears to be about 10 to 15 in. vertical water column, and the water rate is in the vicinity of 25 gal per 1000 cu ft of gas.

*Ball washer* — In the latter part of 1941, a new static washer was put in operation, in which the conventional banks of wood hurdles were followed by successive beds of brick balls of graduated sizes, the smallest being ¾ in. diameter. Water sprays are applied above the ball beds in the usual manner. The washer also contains a rubber-lined cyclone eliminator as a final stage. (See Figure 10.) Considerable preliminary experimentation preceded the full scale adoption of ball beds as gas scrubbing elements, particular attention being directed at the question of their plugging up. Prolonged periods




DETAIL OF BALL SECTION

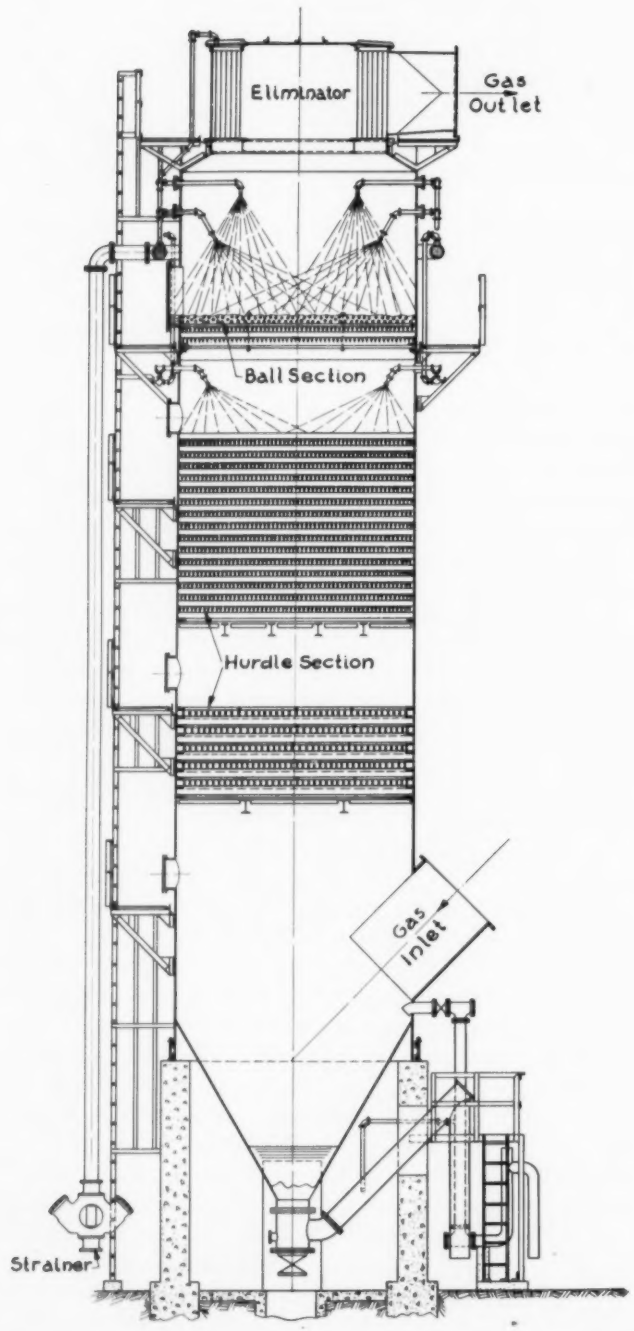



**Figure 10 — In the ball washer, the conventional wooden hurdles are combined with beds of balls of ceramic material.**

of test operation failed to develop indications of fouling, even though the ball beds were, in these tests, exposed directly to raw dust catcher gas.

This use of beds of spheres for gas scrubbing has brought forth some interesting considerations and facts. The individual balls in each successive course lie over the openings between the balls of the course below, so that the bed as a whole constitutes a multitudinous array of successive venturi-like throats and globular baffles. In an 18 ft diameter washer, there are about 60,000 openings in each course of ¾ in. balls; or in a bed 3 in. deep, there are about 250,000 tiny venturi throat and baffle combinations. The dispersion of the gas into small streams and the turbulence of flow are carried to an immense degree. These two fundamental principles of static gas scrubbing are further supported, in the use of ball beds, by the third principle, viz., that of extended wetted surfaces. In a 9 in. bed of 1 in. diameter balls, plus a 3 in. bed of ¾ in. balls, in an 18 ft diameter washer, there are 12,000 sq ft of surface area.

Performance indications for the ball bed washer are encouraging, but there has not been a long enough period of run on this first unit, or on the second unit recently completed, to warrant the publication of figures. At this time, it must suffice to state that we are aiming at a clean-up to below .10 grains on basic iron gas, with a pressure drop of about 12 in. vertical water column, and a water rate of not over 25 gal per 1000 cu ft of gas. A distinct virtue of the ball-bed washer is the fact that it makes use of comparatively cheap and definitely non-strategic material.

*Gas conditioner* — In quite recent years the principle of wetting the dust particles by causing water vapor to condense upon them has been applied to blast furnace gas cleaning. As we have said before, you cannot catch these fine dust particles unless you wet them. When it is recalled that a water-drop from even the finest kind of an atomizing spray nozzle is at least one hundred times larger than a particle of blast furnace gas fume, it is fairly understandable why these fume particles are not wetted or knocked out by the application of any sort of spray which has practical possibilities around an industrial works. It is like trying to hit a gnat with a baseball bat. It is an action that is not easily accomplished by means which come within the scope of primary washers.

However, many of these fine particles can be wetted with comparatively little difficulty by employing the principle of condensing water vapor upon them, a principle constantly occurring in nature in the formation of rain, mist and fog. In fact, it appears that the presence of dust particles is an important aid in forming rain, mist or fog, and that without the presence of dust to act as nuclei, the atmosphere can be and can remain in a super-saturated condition. Consequently this matter of condensing water vapor onto dust particles in gas is not a condition which has to be forced, but rather one which readily occurs if right conditions are established.

These right conditions consist fundamentally of chilling the moisture-saturated gas in a space where there are no other objects for the moisture to condense upon except the dust particles.

The application of this condensation-wetting prin-

ciple is found in the Freyn gas conditioner shown in Figure 11. It is a static tower having no moving mechanical parts. The gas enters the bottom of the tower and leaves at the top. The device and its operation are divided into three steps or stages:

1. The evaporation-scalping stage for removing the coarse dust and for charging the gas heavily with water vapor.
2. The condensation stage for wetting the remaining fine dust particles.
3. The elimination stage for removing the wetted dust particles and entrained water.

In the evaporation stage (the lower part of the tower), hot water is recirculated. The heat in the incoming raw gas is used to evaporate water into the gas, which is later condensed to useful purpose. The removal of heavy bulk dust is also accomplished in this stage, which is equipped with hurdles or brick ball beds for that purpose.

The hot water in the evaporation stage is recirculated by a rubber-lined pump of a type commonly used for heavy duty handling of solids-bearing liquids. To stabilize the build-up of accumulated dirt in the recirculated water, a portion of the recirculate is continuously bled off and make-up is supplied from the condenser stage.

The gas leaves this first stage at between 130 and 140 F, and since it is saturated with water vapor at that temperature, there are between 50 and 80 grains $H_2O$ associated with each cu ft of gas. Moreover, the gas has been scalped of its heavier dust content to a degree corresponding to that effected by the average competent primary washer, which means to about .15 grains dust per cu ft. This is important. We are seeking to wet the difficult particles of dust by condensing water vapor upon them. It would be futile to allow the coarser dust to be present at this point — the dust which is readily removed by sprays and baffles — because the condensing water vapor would go to them by preference, and so waste itself.

Above the middle of the tower is the cooling and condensing stage. Sprays of plant service water, preferably as cold as reasonably possible, cool the gas far below its dewpoint, thus bringing about a heavy condensation of water vapor in the form of fog or rain. If the available plant service water is 95 F, about 40 grains of water vapor per cu ft of gas will be so condensed. With 75 F service water the condensate will be about 50 grains per cu ft of gas. The ratio of condensed water to dust particles is on the order of 200 or 300 to 1. Wetting of the fine dust particles is the function of this second stage of the gas conditioner, and with an availability factor of several hundred to one, this function is carried out quite effectually.

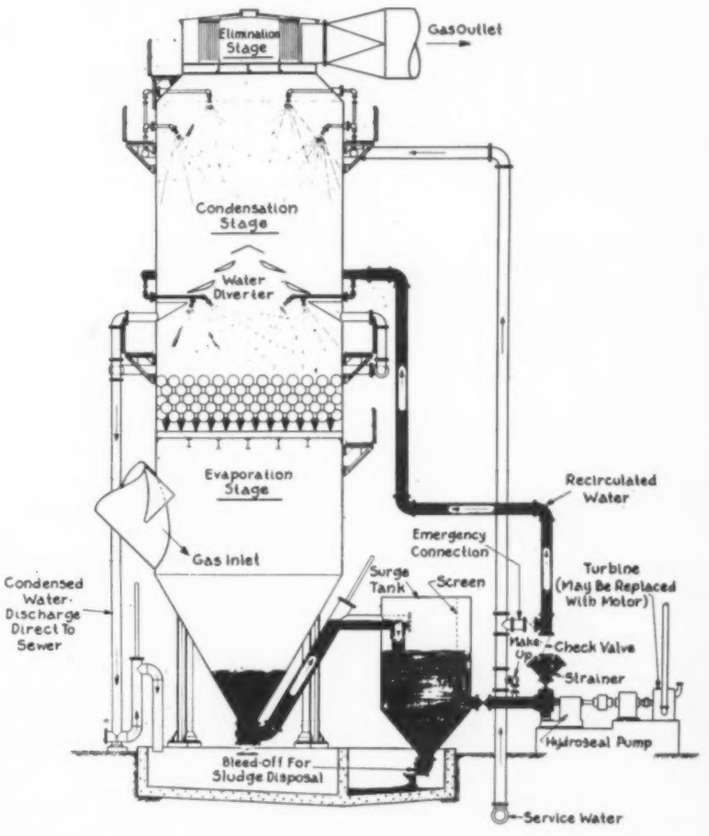
Between the hot stage and the cold stage is a water diverter. It is undesirable to allow the cold water to mix with and chill the hot recirculated water, because evaporation of water vapor into the gas would then be much reduced. The spent condenser stage water is sent direct to the sewer. While the removal of dust in this stage is highly important from the standpoint of gas quality, it amounts to comparatively little in actual poundage, and still less in recoverable values. The degree of contamination of the water used in the condenser stage amounts to about 10 grains of solids per gallon, a point beyond the further practical clarifying capacity of sludge recovery apparatus. In fact, 10 grains per gallon is about the minimum point at which thickeners usually discharge clarified water.

The final stage of the gas conditioner is the rubber-lined eliminator, previously described. The condensing stage and this final eliminating stage cooperate to remove 70 to 80 per cent of dust remaining after the hot stage. The final clean-up is to about .05 grains dust per cu ft of gas.

The gas conditioner, besides constituting a very effectual primary washer in terms of present-day requirements, has the further substantial advantage of greatly reducing the size of required sludge reclamation equipment. In most primary washers, the dust is taken away in water which amounts to at least 25 gal per 1000 cu ft of gas treated. In the conditioner, the dust is removed in the bleed-off from the hot stage. This amounts to only about 5 gal per 1000 cu ft of gas treated. This water is very heavily loaded with dirt, but since the size of a sludge disposal thickener is dictated not by the concentration of dirt in the water but by the quantity of water to be handled, the size of a thickener used in conjunction with a gas conditioner need be only a fraction of that required by the usual primary washer.

The amount of water in transit through the gas con-

**Figure 11 — This gas conditioner, with no moving parts, is based on condensation-wetting principle.**



ditioner is very large. It is on the order of 40 gal per 1000 cu ft of gas handled. Half of this, however, is recirculated water. The actual supply of new water required by this gas cleaner is comparatively low, being about 20 gal per 1000 cu ft of gas.

The gas pressure loss through a gas conditioner is between 12 and 15 in. vertical water column.

### Secondary Wet Cleaning

As the situation exists today, primary gas washers of the improved type will clean to between 0.05 and .15 grains. In order to extend the scope of gas utilization to take in coke ovens, gas engines, and very small checker stoves, it is necessary that the gas be cleaned to 0.02 grains per cu ft, or better. This means that the dust removal is directed at the last per cent of the total dust in the downcomer gas. Figure 1 indicates that this portion consists of the very smallest particle size class — the several hundred-thousandths or several millionths inch sizes. These minute particle do not settle out by gravity. They are not caught by impingement on fixed wetted surfaces because their buoyancy is so great that

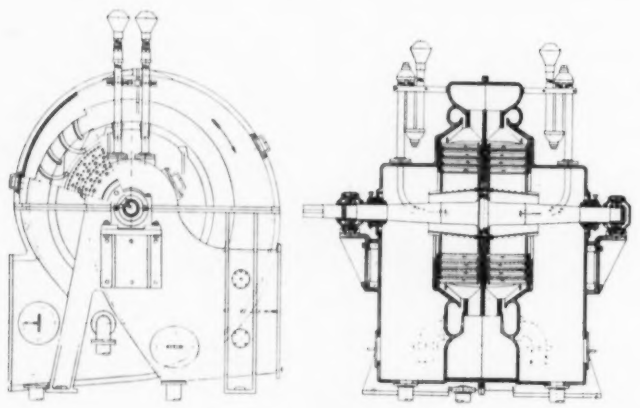


**Figure 12 — This disintegrator consists of a cast iron casing enclosing two stationary baskets and a motor-driven rotating basket.**

they follow the path of the gas regardless of how tortuous it may be. They cannot be wetted down by means of a spray of a fineness within the realm of practicability with service waters in most industrial plants. These minute particles seem, many of them, to be even beyond the scope of wetting by condensing moisture. They are in the size class, or at least on the borderline, of what are known to meteorologists as "permanent atmospheric impurities," which appear to range in size from a maximum of four one-hundred thousandths of an inch (.00004 in.) down to four ten-millionths of an inch (.0000004 in.), and are not removed from the air even by the formation of fog, clouds or rain.

Different measures than those now employed in primary gas cleaning must be enlisted to capture these fine fume particles. Aside from the none too practical scheme of filtering them out, there are two basic principles for collecting these minute particles in wide and well established commercial use. One principle is to beat water into an exceedingly fine mist by violent agitation in conjunction with the gas-borne dust, thus securing agglomeration by brute force. Another principle is to drive the particles forcibly, by means of an electric charge, against a wetted surface of opposite polarity. The first principle is employed in the disintegrator, the second in the wet-type electrical precipitator.

*Disintegrator* — The Theisen disintegrator is widely used for fine-cleaning blast furnace gas. Theisen disintegrators are also applied to other industrial gases. About 300,000 cfm in new Theisen disintegrator capacity was installed in the U. S. A. in a recent twelve-month period, bringing the total installed capacity of disintegrators in the U. S. A. and in Canada to about 2,000,000 cfm.

The Theisen disintegrator should not be confused with the Theisen drum-type washer, which has been used in connection with gas engine plants in this country for many years. While serving substantially the same purposes, the disintegrator is based on different principles, has a much greater capacity, produces a higher degree of gas cleanliness, and is more efficient in power and water requirements.

The Theisen disintegrator, shown in Figure 12, consists of a substantial cast-iron casing, enclosing two stationary baskets and a motor-driven rotor basket. The casing is provided with integrally cast, double scroll-shaped gas inlets, and a single gas outlet. The rotor is carried on a heavy forged shaft. The rotor assembly consists of perforated spray cones and concentric rows of stainless steel bars, arranged parallel to the axis of rotation. The stationary baskets consist also of concentric rows of stainless steel bars, which alternate with those on the rotor. The baskets are secured to the casing in such a way that they can be removed with the rotor. The top half of the casing may be removed for inspection and withdrawal of the rotor, leaving the gas inlets and outlets with all connections intact.

The water used for washing is injected by gravity through water-sealed traps to the center of the perforated cones. Centrifugal force distributes the water over the rotary and stationary bar system, and the action between the rotating and stationary bars atomizes the water into a mist of minute particle sizes. Under the condition of great violence, the water agglomerates with the dust, wetting it so that its removal from the gas stream is accomplishable.

In addition to the ability to clean gas, the disintegrator has the optional characteristics of acting as a gas booster. This function is obtained by adding fan blades to the rotor. Any desired pressure increase up to a maximum of 16 in. of water, may be developed.

The capacity of the Theisen disintegrator customarily used for blast furnace gas cleaning is 45,000 cfm. Water requirements range from 4 to 8 gal per 1000 cu ft of gas, and the power requirements from 4 to 10 kw per 1000 cfm of gas, depending upon the degree of cleanliness required and the pressure-boosting demand. The range of cleaning possibilities with blast furnace gas is between .02 and .005 grains dust per cu ft.

An essential accessory to a disintegrator is the moisture eliminator which follows it. The standard type now used is the rubber-lined cyclone eliminator previously described in connection with primary gas cleaning. It has been said, and with considerable truth, that the disintegrator wets the dust, and the moisture eliminator removes it from the gas.

One of the most significant characteristics of the disintegrator is its indifference to the quality of the incoming gas. A disintegrator will clean just as well with .30 grain dust per cu ft in the entering gas as with .10 grains. Thus it is not necessary to provide more than a simple precooling tower as a primary washing stage if disintegrators are to follow.

*Electrical precipitator* — There is an aggregate of about two million cfm capacity in wet-type electrical precipitators operating on blast furnace gas throughout the country, and at least an additional half-million cfm is in the process of installation.

The principle of electrical precipitation, although involving highly technical physio-electrical phenomena, is generally familiar to all and will be touched upon but briefly here. If suspended particles are placed in a high voltage electric field, they will receive an electric charge and will move toward one or the other of the electrodes between which the electric field is established. If one electrode is a pipe with a smooth interior, and the other electrode is a wire axially suspended in the center of the pipe, the field is strongest around the wire and weakest near the surface of the pipe. The charged dust particles will move from the strong part of the field toward the weak part of the field; that is, they will collect on the walls of the pipe. If the pipe is vertical and if a film of water is kept flowing down the walls, the collected dust will be embedded in the film of water and washed away.

It is found that best results are obtained with unidirectional rather than alternating current, and when the discharge electrode (the suspended wire) is of negative polarity.

These, then, are the elementary features of the electrical precipitator of the Cottrell type for fine-cleaning blast furnace gas. A typical precipitator is shown in Figure 13. This is a 208-pipe unit. Each pipe is 8 in. diameter and 15 ft long. The gas enters the sides of the precipitator shell, passes upward through the pipes, and leaves the precipitator through two outlets in the top cone sheet.

The electrical equipment for a precipitator unit consists essentially of a transformer for raising alternating current at usual plant voltage to about 50,000 volts, and a high voltage mechanical rectifier for changing the alternating current to 50,000 volt uni-directional current. One side of the rectifier is grounded, as are the precipitator pipes, while the other side is connected to the precipitator wires suspended in the pipes, and very carefully insulated from them. The electrical equipment is usually furnished in duplicate for standby purposes.

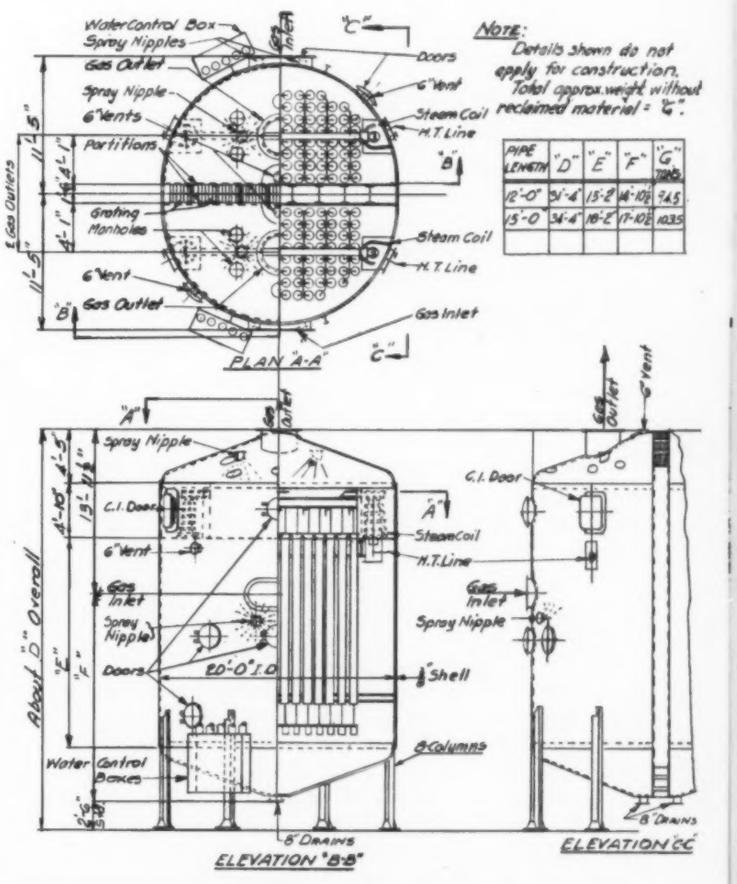
It is found that wires of rectangular section, twisted about one turn in 8 or 10 inches, produce a more effectual electrical field, due to the relatively sharp edges, than do plain round section wires.

The power input required for an electrical precipitator is at a rate of approximately 0.2 kw per 1000 cfm capacity; or, about 300,000 cu ft of gas can be handled at the expenditure of 1 kwhr. The required water rate on precipitators is about 2.2 gal for each 1000 cu ft of gas treated. Steam consumption (used to keep the insulators clean and dry), amounts to about 2400 lb per 24 hr on practically any size of precipitator unit.

The capacity of an electrical precipitator unit is based upon the dust content of the incoming gas and the required cleanliness of the outgoing gas. A precipitator of given size can clean more gas to say 0.01 grains if the incoming gas contains 0.1 grains dust per cu ft, than if it carries 0.3 grains. Figure 14 indicates the capacity of each 15 ft by 8 in. diameter precipitator pipe (or tube) on this basis. The horizontal coordinate is in cfm per tube. The vertical coordinate is in grains dust per cu ft of incoming gas. Each curve represents a certain cleanliness of outgoing gas. From these data it can be ascertained that with 0.30 grain incoming gas, one tube will clean about 200 cu ft of gas per min. to 0.01 grains. If the incoming gas contains only 0.10 grains dust, then one tube will clean 300 cfm of gas to 0.01 grains.

The converse is also true, namely, at a given rate of gas flow per pipe, an improvement in the quality of

**Figure 13 — Typical electrical precipitator containing 208 pipes, for fine cleaning blast furnace gas.**



incoming gas results in a finer quality of outgoing gas.

There is a limiting point in the capacity of a precipitator pipe. It is important that the volume rate not exceed 450 cfm in an 8 in. diameter pipe. This is equivalent to a gas velocity of about 22 fps.

The foregoing discussion brings us back to a previously mentioned point in favor of improving primary gas cleaning. It works to the advantage of subsequent fine cleaning in electrical precipitators. This fact has been particularly impressive where improvements have been made in primary washers which discharge to electrical precipitators.

The above figures for wet precipitator operation refer to those with 8 in. diameter pipes. There have recently been put in operation, however, several large units having 12 in. diameter pipes. The performance of these units has shown at least 90 per cent dust removed, so that with a reasonably good incoming primary gas of say .15 grains dust per cu ft, the final gas from the precipitator contained distinctly less than .015 grains. This performance qualifies the 12 in. pipe precipitator to rate as a fine-cleaning device. Per unit of conventional rated capacity, there is no appreciable difference in cost between the 12 in. pipe precipitator and the 8 in. pipe precipitator. The 12 in. design has distinct advantage in that its ultimate capacity is almost 20 per cent higher than the ultimate permissible capacity of the 8 in. pipe unit, thus offering very much greater flexibility. It is even possible that the 12 in. pipe precipitator may displace the 8 in. as the standard design for blast furnace use. On the face of it, this matter of pipe size might seem to be more an affair of interest to the precipitator furnisher rather than to his client, but actually it is a matter of major importance in the application of precipitators in general because it tends considerably to modify one of the less favorable features of precipitator utilization, namely, the distinct limitation in flexibility and overload capacity.

With regard to spare unit availability, it is often the custom to build wet type electrical precipitators in what is termed the completely divided type. The cylindrical shell and its complement of pipes are separated both electrically and physically into two independent parts. Vertically disposed double dividing walls with air space between, supplemented by appropriate gas valving, provide for shutting down one part so completely as to permit actual entry of that part while the other is operating. Here again the 12 in. pipe design shows to advantage, since the 100 per cent overload forced upon the going half of the unit is far more successfully handled with 12 in. pipes than with the 8 in. size.

## Cost of Gas Cleaning

*Units* — We shall indicate a number of approximate, comparative, basic cost figures for various forms of gas cleaning equipment, and then select and analyze a hypothetical case which might be regarded as fairly typical of a situation facing blast furnace operations with respect to gas cleaning. For a gas unit rate, we shall use 90,000 cfm representing between 950 and 1050 net tons of daily pig iron production.

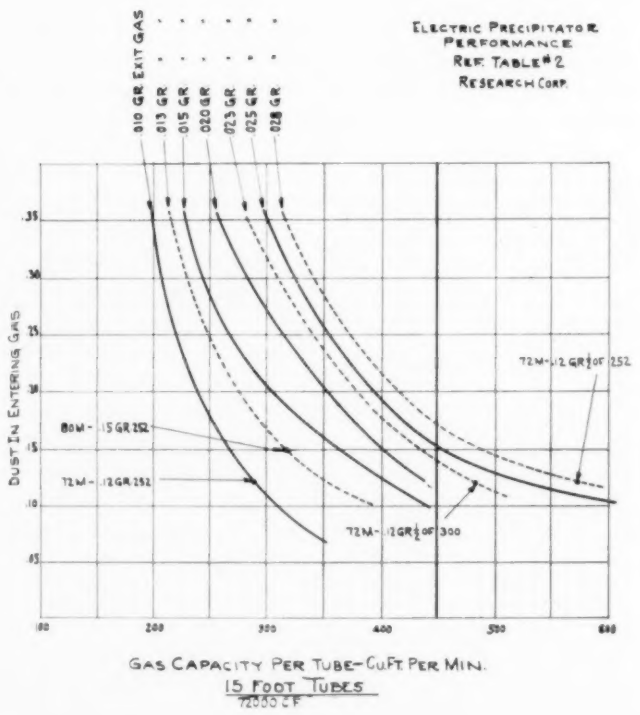
It should be pointed out that the installation cost figures must be regarded as being relative only. Installation costs do not cover such items as sewers, water mains brought to the site, or distributing gas mains. These items would be substantially equal for practically any gas cleaning set-up, but might be far from equal in two or more different plants.

*Unit costs of primary washing* — A completely new primary washer capable of cleaning to .15 grains per cu ft, installed, including foundations, would cost approximately $60,000.00. A washer of this sort would be appropriate ahead of electrical precipitators. The water consumption would be about 2400 gpm. In passing through the washer, the gas would lose about 8 in. vertical water column pressure. No mechanical power need be required, but the water must be pumped to about 45 psi pressure, which would call for about 78 kw of power.

An ordinary static cooling tower, such as might be used ahead of disintegrators, would cost, new, about $35,000.00. The gas pressure loss would be not over 4 in. The water rate would be about 2000 gpm at 35 psi pressure, calling for about 50 kw of power.

*Unit costs of a secondary cleaning* — An electrical precipitator of the wet type, fully divided into two parts and capable of cleaning 90,000 cfm gas from .15 grains down to about .015 grains with both parts operating, or to about .03 grains in emergency with only one part operating, would cost, complete with foundations, buildings and valves, about $110,000.00. It would use about 200 gpm of water, 150 lb of steam per hour, and about 25 kw of power, including that for water pumping. The gas pressure loss would be about 2 in. vertical water column.

**Figure 14 — Curves showing capacities for 15 ft x 8 in. precipitator tube.**



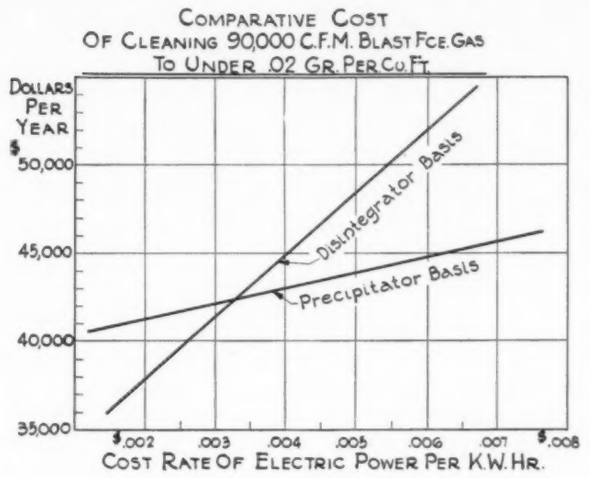



**Figure 15 — Chart showing comparative cost of cleaning blast furnace gas by two methods.**

Disintegrators for fine-cleaning 90,000 cfm gas would consist of three units of 45,000 cfm capacity each, so that one unit would be a spare. A plant of this sort, complete with foundations, motors, housing and two moisture eliminators, would cost about $90,000.00. The water requirement would be 550 gpm. The driving power would depend on whether these machines were of the pressure type or the non-pressure type. With the latter (the non-pressure type), a power input of about 380 kw would result in no pressure gain or loss. The high-pressure booster type disintegrators would develop an overall net pressure rise of 12 in. vertical water column, and would call for 600 kw power input at a gas rate of 90,000 cfm. Cleaning at all times would be to .015 grains, or better.

*Hypothetical case* — We are now ready to analyze a hypothetical gas cleaning project. A blast furnace is producing 1000 net tons of iron per day, and about 90,000 cfm of gas. It is proposed to fine-clean all of this gas so as to make it useable both for its own stoves and for the stoves at associated furnaces, it being planned to equip all stoves with modern high-efficiency checkers. The cleaning is to be carried to .02 grains or better. Either there has been no wet gas cleaning heretofore at this furnace, or the existing equipment is beyond salvaging.

A selection of fine-cleaning equipment affects the course of procedure from the very start. The choice of fine-cleaning is between (a) electrical precipitator, and (b) disintegrators. The former would call for a good primary washer cleaning to .15 grains, and a 224-pipe (12 in.) precipitator of the divided type. The latter would require a simple cooling tower and three disintegrators. Both set-ups would have adequate spare provision, although the precipitator set-up might yield .03 grain gas in an emergency, whereas the disintegrators have a standby unit so that under .02 grain gas would be had at all times. Table II shows the significant quantities attaching to the two procedures.

**TABLE II**

**90,000 cfm Gas Fine-Cleaned to .02 Grains**

| | (a) Precipitator basis | (b) Disintegrator basis |
|---|---|---|
| Installation cost: | | |
| Primary washer | $ 60,000 | $ 35,000 |
| Secondary units | 105,000 | 90,000 |
| | $165,000 | $125,000 |
| Water, gpm | 2,600 | 2,550 |
| Steam, lb per hr | 150 | ... |
| Electric power (including pumping), kw | 103 | 440 |
| Pressure drop, in. $H_2O$ | 10 | 4 |

We are now faced with evaluating the costs of steam water and electric power, as well as capital costs, all of which may be different at different plants, and hence would variously affect the ultimate picture. The differences in water and steam quantities are relatively small items. The influencing factors are unit power costs and capital costs. We have encountered capital charges applied to new work in iron and steel plants as high as 23 per cent and as low as 13 per cent. We believe that the one is as excessive as the other is deficient, and have taken the figure of 16.5 per cent as a reasonable rate for capital costs applicable to equipment of this sort. The figure is made up of:

5 per cent interest
6.5 per cent amortization (15 yr.)
2 per cent contingencies
3 per cent taxes

16.5 per cent

There may be those who cannot agree with these figures. It is precisely for that reason that they are displayed here in detail. Any reader may write his own ticket, and apply it to the subsequent analysis.

The blast furnace operator may not be particularly interested in capital costs, since they do not ordinarily appear on his pig iron cost sheet, but these costs are very present none-the-less, and usually have a determining influence upon whether a paper project is converted into structural reality.

Power cost is a strongly influencing factor. It may be entirely misleading to charge for power at a rate shown on last month's cost sheets. In some plants the imposition of several hundred kw additional steady load might necessitate the installation of additional generating equipment, with capital charges of its own, and a consequent increase in the general power cost rate for a long period of time. At other plants, the additional power load might be taken up by existing and going boilers and generators, using otherwise bled gas as a basic source of energy, so that the actual cost of the additional power might be virtually nothing.

The electrical precipitator institution carries a higher

installation cost but uses relatively little power. A Theisen disintegrator institution costs less to install but consumes considerably more power. If one evaluates capital charges high enough, and electrical power low enough, one can develop a favorable picture for disintegrators; vice versa, of course, for precipitators. The only fair basis is the actual "out-of-pocket" effect on the plant which one institution will have over against the other.

Unless careful scrutiny is given such factors, it is not difficult to enlist the services of figures to help prove what we desire to prove.

Table III is an analysis of comparative annual costs, based on water at $5.00 per million gallons, steam at $0.20 per thousand pounds; capital charges at 16.5 per cent; and power at a sliding scale from $0.002 to $0.006 per kwhr.

**TABLE III**

**Comparative Annual Costs of Cleaning**

**90,000 Cfm Blast Furnace Gas to .02 Grains**

| | (a) Precipitator basis | (b) Disintegrator basis |
|---|---|---|
| Capital charges (16.5 per cent) | $27,200.00 | $20,000.00 |
| Water | 6,500.00 | 6,400.00 |
| Steam | 250.00 | ..... |
| Pressure drop at .76 lb steam per hr per in. per 1000 cfm | 1,100.00 | 440.00 |
| Labor and maintenance | 4,500.00 | 3,500.00 |
| Total, excluding power | $39,550.00 | $30,940.00 |
| Total, including power: | | |
| At $0.002 per kwhr | $41,198.00 | $37,980.00 |
| At $0.004 per kwhr | 42,836.00 | 45,020.00 |
| At $0.006 per kwhr | 44,494.00 | 52,060.00 |

These values are shown graphically on Figure 15. The graphs cross a little above $0.003 power. If the additional block of electric power put into gas cleaning at a given plant costs more than $0.003 per kwhr, it is more economical to use precipitators; if less than $0.003 per kwhr, disintegrators are more economical. This conclusion is based upon the conditions set forth in the above selected case of cleaning 90,000 cfm gas to .02 grains, or less, dust per cu ft.

In cases which call for boosting of the gas pressure, disintegrators will show economically more favorably than precipitators at even a higher rate of power cost than 3 mills per kwhr. This is because of the pressure-boosting feature that can be incorporated in Theisen disintegrators. With precipatators, a separate boosting station would be required.

The above analysis, comparing two gas-cleaning schemes, is based on an operating year of 8,000 hours. Within the memory of living man, there have been industrial years that did not contain 8,000 operating hours, and one should not be accused of being unduly cynical if it were suggested that a somewhat slack year or two could occur again. It costs less to have cheaper equipment standing idle. If, for example, we evaluate these two gas-cleaning schemes on the basis of 6,000 hours per average year instead of 8,000, we would find that the crossing point on Figure 16 would be at about 4 mill power instead of 3 mill power.

### Sludge Disposal

*Recoverable values* — The by-product of wet gas cleaning is a substantial volume of water contaminated considerably with solid material consisting of the stuff that is removed from the gas in the cleaning process. By reference to Table I, it appears that this material may consist of between 50 and 60 per cent iron oxide, 30 to 20 per cent silica, alumina, lime and magnesia, about 7 per cent carbon, and 10 per cent alkali salts, which latter are largely in solution.

Inasmuch as approximately 3 grains of dust are removed from each cu ft of gas in primary washing, and inasmuch as about 25 gal of water are used per 1000 cu ft of gas, each gallon of water contains about 120 grains of solid material, of which 90 per cent is insoluble and is present more or less in suspension so long as the water is flowing or otherwise in motion.

From a 75,000 cfm washer there are discharged, daily, approximately 22 tons of suspended solids containing between 40 and 50 per cent of iron. Even at as modest a value as $0.05 a unit, this material has a potential worth between $55.00 and $65.00 a day; easily $20,000.00 a year. This value should, and indeed does, justify an investment in ways and means for its recovery.

*Settling basins* — In the blast furnace field, these ways and means invariably are settling basins, where the discharge water from the washer takes on a state of relative quiescence and most of the suspended solid matter sinks to the bottom. These settling basins may consist of simple concrete sumps, or even of informal ponds in a convenient depression in the land about the plant, from the bottom of which periodically the accumulated sludge is dredged with a grab bucket on an overhead or locomotive crane. This is a relatively cheap but none too satisfactory system. Settling is not overly efficient, particularly as the basin progressively fills with solid material, and as, in consequence, the velocity of water through the basin increases. The sludge as dredged is in a horribly sloppy state, and a dripping gondola car of it seems eloquent with the appeal: "Where do I go from here?" During dredging operations, the mud is violently stirred up and unless there is a spare basin, the discharge water is dirtier than the incoming water from the washer. With stream and waterways pollution receiving ever-increasing disapproval from all sides, the make-shift sludge basin seems well on its way out.

*Dorr thickener* — The most widely used modern equipment for sludge reclamation and water clarification at blast furnace gas cleaning institutions is the Dorr

thickener, shown in Figure 16. It consists of a steel or concrete tank from 40 to 200 ft in diameter, approximately 6 ft deep, and having a centrally depressed conical bottom. The contaminated water from the gas washer is brought in a trough to the center of the tank, from which point it disperses radially in all directions with ever-decreasing velocity. The circumference of the tank is bounded by a carefully leveled launder or weir over which the clarified water flows in a thin cascade and is collected in a suitable trough connecting to sewer.

The solid material in the water settles to the conical bottom of the tank where it is slowly plowed toward the low center point by radial sweeps (Figure 17) carrying angularly disposed shoes, and rotating at a rate of perhaps one revolution in 5 to 25 minutes, depending on the size of the thickener. (A peripheral tip speed of about 25 fpm is maintained.) There is an outlet in the depressed apex of the conical bottom of the tank through which the sludge passes to a special disphragm pump, capable of delivering the sludge to a filter.

The sludge from the Dorr thickener contains about 50 per cent water and has a thin, soupy consistency. The final filter cake contains about 25 per cent water and has a consistency and appearance something like soft chocolate. This filter cake is in a state that can be handled with reasonable facility if not permitted to accumulate in too large heaps. It can be readily conveyed on a belt and mixed with other materials for sintering.

*Reclaimed water* — The clarified discharge water from the thickener still contains between 10 and 20 grains of suspended solids per gal. This consists of the smallest size class of material washed out of the gas, the minuteness of which particles we have dwelt on at great length in previous paragraphs. In a practical sense, these particles will not settle out of water, be the state of quiescence ever so prolonged. The metallic value in this residual solid matter in the clarified water is negligible since it is of scarcely 10 per cent in iron content.

Water containing 15 grains of suspended solids per gallon is fairly clear water. Many industrial supplies of fresh water will contain this amount of contamination. The main water supply to one of the large steel producing centers of this country contains between 20 and 30 grains of solids per gallon.

The function of the Dorr thickener does not extend to purifying the water of dissolved solids and these may be present ot the extent of 10 or 12 grains per gal. However, in localities where careful husbanding of water is required, 90 per cent of such water may be restored to the system. With 10 per cent of fresh make-up water introduced, the salinity of the system will not build up to more than 7 per cent of that of sea water.

The Dorr thickener is at least 80 per cent efficient in removing all solids from gas washer water, and well over 90 per cent effective in extracting the iron-bearing values. The thickener and filter combination is today the most practical and satisfactory means for recovering the values in blast furnace gas washer discharge, and at the same time restoring this water to a state of reasonable industrial utility.

*Thickener rating* — The capacity of the thickener is usually expressed in gallons of water per day per sq ft of area. Figure 18 is a graphical representation of the unit rating of the thickener over a range of clarifications. Suppose that it is desired to clarify to 10 grains per gal. The unit rating of the required thickener is, from the full-line graph, 900 gal per day per sq ft. If a primary washer is using and discharging 2000 gpm of water, or 2,900,000 gal per day, the area of the required thickener is 2,900,000 divided by 900, or 3,700 sq ft. A 70 ft diameter thickener would have this area.

*Fine-cleaner water* — Particular attention is drawn to

**Figure 16 — General view of typical Dorr thickener installation.**

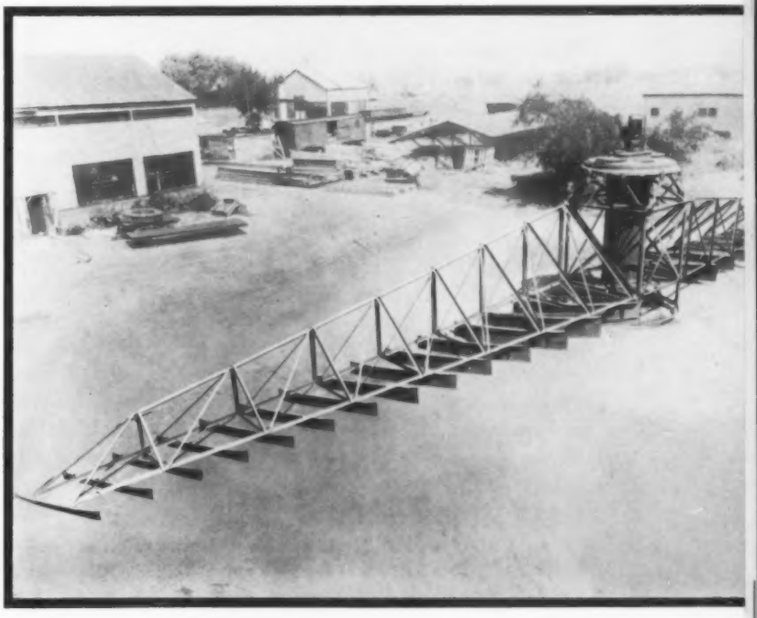


**Figure 17 — Radial sweeps in the thickener slowly plow the settled sludge toward the center of the basin.**

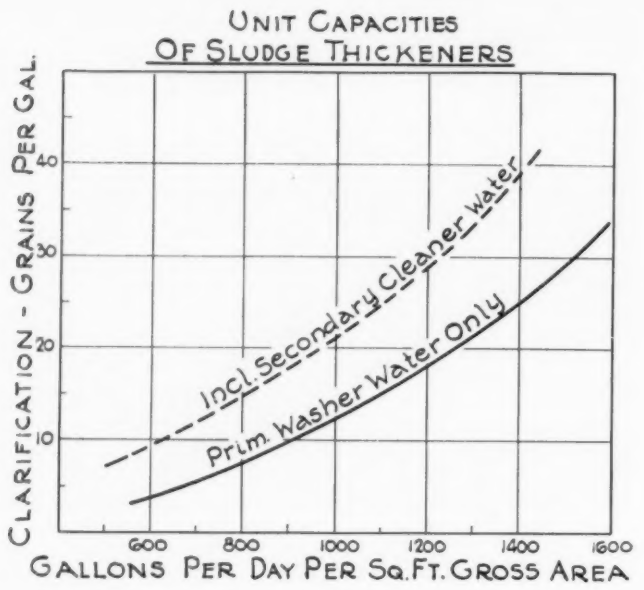



**Figure 18 — Chart showing capacity of sludge thickeners for various degrees of clarification.**

the broken-line graph on Figure 18. It represents the unit capacity of a thickener if the water from the fine-cleaners is sent to the thickener along with the primary washer water. In such event, the unit rating is reduced by about 25 or 30 per cent. For a 10 grain per gal clarification, the rating of the thickener would be only 600 gal per day per sq ft of area. With all the emphasis that has been placed upon the extreme fineness and unsettleability of the microscopic size class of dust particles that are removed in the fine-cleaning process, it should not be difficult to understand why the area of the thickener must be increased if it is obliged to deal with the discharge water from fine-cleaners. If fine-cleaner discharge water is involved, a thickener 5400 sq ft in area, or 82 ft in diameter would be required in the above example. The cost of a Dorr thickener is in the general category of $9.50 per sq ft of area, so that the additional cost of an 82 ft diameter unit over against a 70 ft unit is in the vicinity of $16,000.00. The value of the additional sludge recovered from the fine-cleaner water cannot be placed at more than $200.00 per year by the most optimistic appraisal, which represents a gross return of less than 2 per cent on the additional investment. One is strongly led to the categorical statement that the water from a fine-gas-cleaning institution should be discarded and not added to the sludge disposal plant load. In those cases previously described where water must be reclaimed and returned to the system, and where a certain amount of bleed-off and make-up is required to keep the salinity of the system within limits, it would be doubly appropriate to designate the fine-cleaner discharge water as the bleed-off point.

In comparison with the 70 or 80 ft thickener called for by the usual primary gas washer, it is interesting to note that a washer in which part of the water is recirculated, as in the gas conditioner described previously, would require a thickener less than 40 ft in diameter.

*Tray thickener* — A supplementary notation is in order to the effect that where ground space is constricted, it is feasible to use the tray-type thickener in which several compartments are stacked one above the other, as shown in Figure 19. With such an arrangement, the unit capacity in gal per day per sq ft of gross area is reduced approximately 16 per cent below the rating of the single-compartment thickener. It is obvious that with such an arrangement, it is likely to be necessary either to elevate the primary washer or to resort to re-pumping the sludge-bearing water from the washer, neither of which measures are done without attendant cost.

### Influence of Furnace Conditions upon the Degree of Gas Cleaning

When a blast furnace operator purchases and installs a gas washer exactly like the one at his colleague's furnace, he expects it to perform in much the same manner. There have been instances in which both the operator and the gas washer salesman have been mystified and disappointed to find that the good performance of the first installation was not duplicated in the second. It has worked the other way, too, the second installation showing a cleaning ability far better than the example, set by the first, would have led one to expect. In such case, the mystery would actually be just as deep but it would not seem so deep because the element of disappointment would not be coupled with it.

One frequently hears an attempt at explaining the situation by connecting the occasional poor demonstration of an otherwise good gas washer on the grounds that the furnace has a high flue dust production. When the shoe happens to fit, the explanation is accepted. When it doesn't fit — well, then the explanation is not advanced to begin with. And indeed it fails to fit frequently enough to justify discarding the flue dust make as an index of washer performance. One of the best washer performances we have ever secured has been on a furnace making 400 lb of dust per gross ton of pig, and one of the most disappointing performances attached to a 75 or 100 lb flue dust make.

It is not the quantity of dust that issues with the furnace top gas, but rather its quality, that makes for ease or difficulty in primary washing. Any furnace condition which makes for the emission of fine, fumy stuff in the top gas spells trouble for the primary washer, as we have stated and implied numerous times in the foregoing paragraphs.

The source of such fumy material is in the furnace charge. An ore, coke or limestone that has an uncommonly high alkali content will result in fumy gas, difficult for a primary washer to clean to conventional figures. Then again, a charge which is not a fume-producer when the furnace is making basic iron, may show a very fumy gas when the furnace is making high silicon iron. The resulting gas may be distinctly more difficult to clean. We have had the opportunity recently to log the performance of primary washers with the furnaces on various grades of pig iron. Figure

20 shows the coordinated data, viz., grains of dust in the gas from the washers and per cent silicon in the pig iron at the cast following the dust test. The two graphs refer to two washers of different types at two furnaces in different parts of the country. One washer was directed at cleaning to .05 grains, and did so infallibly so long as the furnace was not making iron above 2.25 per cent silicon. The other type of washer was intended to clean to between .10 and .15 grains. It stayed well within specifications on basic and up through malleable and No. 2 foundry iron, but with the furnace making No. IX foundry (3.00 per cent Si), the washer clean-up was .20 grains.

This effect of furnace conditions upon the degree of gas cleaning is more in evidence with primary washers than with fine-cleaning institutions. In the case of electrical precipitators, it would be manifest to the extent that the gas coming to the precipitator from the primary washer has a higher dust content, and since the precipitators seems to work essentially on a percentage basis, the dust content of the discharge gas would probably be slightly higher.

With disintegrators, the effect of fumy gas seems hardly to be felt at all. The most difficult kind of gas to clean is that from ferro-manganese operation. At one ferro furnace, the best that can be done in the primary stage, even with two towers in series, is a clean-up to about 1.0 grains per cu ft. A disintegrator then takes this gas, however, and cleans it to an average of .006 grains, the maximum test over several months of logging showing less than .01 grains per cu ft.

### Ferro-Manganese Gas Cleaning

The last paragraphs above lead us to make further commentary on the general topic of ferro gas cleaning. Unfortunately, this commentary does not embody a skillful solution of this exceedingly perplexing problem.

Wet cleaning of ferro gas is fraught with substantial difficulties. In primary washing, the use of hurdles or baffles of any kind directly on the gas as it comes from the dust catcher is precarious. A precooling and scalping stage of considerable dimensions, with nothing but water sprays, is highly desirable if the ensuing hurdle arrangement is to be kept from plugging up with an uncomprising deposit of a complex lime-manganese mineral. The only successful fine-cleaning institution we know of on ferro gas is the Theisen disintegrator installation referred to above. This is satisfactory enough from the standpoint of final gas cleanliness, but it is burdened with the necessity of regularly shutting down the disintegrator unit after a run of eight weeks, at most, in order to chip from the bars a rock-like deposit of this lime-manganese mineral. This operation has been carried on for twelve years, and it is probably the best ferro gas cleaning arrangement in existence, but it is far from ideal.

Most ferro gas is dry-cleaned. This classification extends from no cleaning at all beyond a dust catcher, into which category numerous merchant ferro furnaces fall, to the utilization a few years ago at one ferro operation in connection with a large steel plant, of dry-type electrical precipitators. The gas was cleaned to about .20 grains. As far as the precipitators were concerned, the operation was apparently satisfactory enough. The problems presented by (a) the accumulated dry dust, (b) the necessity of partly pre-cooling the gas so as to approach but not quite reach the temperature of dewpoint, and (c) the attempt to reheat the gas, after cleaning, by means of a heat exchanger involving the hot, raw gas, were, to put it mildly, of a lively if not incorrigible nature.

Usually ferro gas is burned in stoves and boilers, hot and raw as it comes from the dust catcher. The excess is bled from the furnace bleeder in the colored plume that identifies the ferro furnace for miles around.

The ferro gas cleaning situation is rather definitely in the unsatisfactory category.

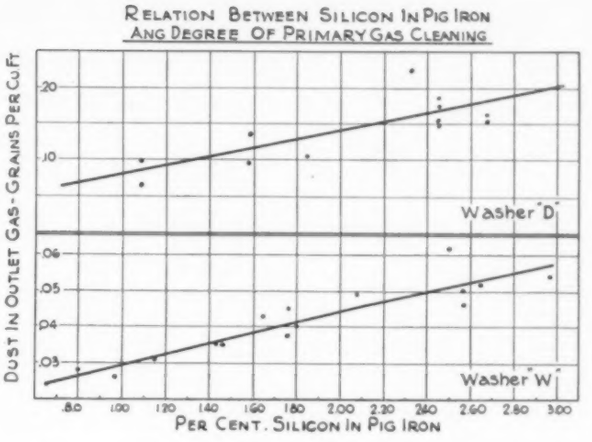
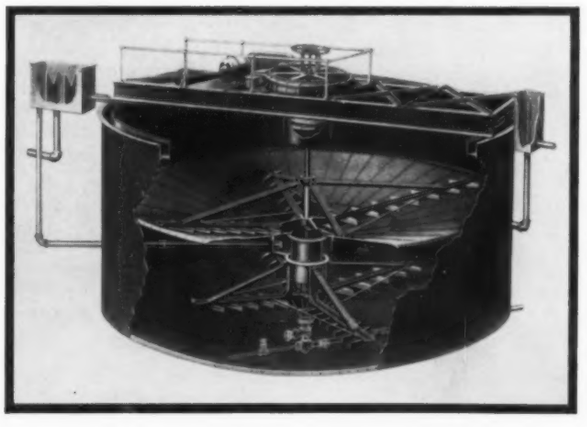



**Figure 20 — Chart showing relation between silicon in pig iron and the degree of primary gas cleaning.**

**Figure 19 — General arrangement showing construction of tray type thickener.**



### Conclusion

The matter of conditioning of blast furnace gas is considerably more than a mere incidental affair in the iron and steel game. The production of pig iron is

## APPENDIX A

### Derivation of Water Vapor Content of Blast Furnace Top Gas

*Minimum:* Rich, dry ore. Dry stone and coke. Low coke rate. Considerable scrap in charge. Cold dry weather.

| | *Lb $H_2O$ per cu ft gas* |
|---|---|
| .028 lb ore per cu ft of gas at 2 per cent moisture and $H_2O$ crystallization | .00056 |
| .0137 lb coke per cu ft gas at 1.5 per cent moisture and $H_2O$ crystallization | .00021 |
| .0068 lb stone per cu ft gas at .5 per cent moisture and $H_2O$ crystallization | .00003 |
| .75 cu ft air per cu ft gas at 1.5 grains $H_2O$ per cu ft ÷ 7000 (assume 65 per cent reverts to $H_2O$) | .00010 |
| | .00090 |

.0009 x 7000 = 6.3 grains $H_2O$ per cu ft of dry gas.

*Maximum:* Lean, wet ore. Wet coke. High coke rate. Humid weather.

| | *Lb $H_2O$ per cu ft gas* |
|---|---|
| .0285 lb ore per cu ft gas at 15 per cent $H_2O$ | .00427 |
| .0143 lb coke per cu ft gas at 7 per cent $H_2O$ | .00100 |
| .0100 lb stone per cu ft gas at 2 per cent $H_2O$ | .00020 |
| .75 cu ft air per cu ft gas at 10 grains $H_2O$ per cu ft ÷ 7000 (assume 65 per cent reverts to $H_2O$) | .00170 |
| | .00717 |

.00717 x 7000 = 50.10 grains $H_2O$ per cu ft of dry gas.

*Typical.*

Northern practice: 54 per cent Fe in ore
1800 lb coke per gross ton pig.
4 grains $H_2O$ in air.

| | *Lb $H_2O$ per cu ft gas* |
|---|---|
| .0277 lb ore per cu ft gas at 10 per cent $H_2O$ | .00277 |
| .0132 lb coke per cu ft gas at 4 per cent $H_2O$ | .00053 |
| .0069 lb stone per cu ft gas at 1 per cent $H_2O$ | .00007 |
| .75 cu ft air per cu ft gas at 4 grains $H_2O$ per cu ft ÷ 7000 (assume 65 per cent reverts to $H_2O$) | .00028 |
| | .00365 |

.00365 x 7000 = 26 grains $H_2O$ per cu ft dry gas.

Southern practice: 40 per cent Fe in ore
2000 lb coke per gross ton pig.
7 grains $H_2O$ in air.

| | *Lb $H_2O$ per cu ft gas* |
|---|---|
| .0312 lb ore per cu ft gas at 12 per cent $H_2O$ (including crystallization) | .00374 |
| .014 lb coke per cu ft gas at 4 per cent $H_2O$ | .00056 |
| .0065 lb stone per cu ft gas at .5 per cent $H_2O$ | .00003 |
| .75 cu ft air per cu ft gas at 7 grains $H_2O$ per cu ft ÷ 7000 (assume 65 per cent reverts to $H_2O$) | .00049 |
| | .00482 |

.00482 x 7000 = 34 grains $H_2O$ per cu ft dry gas.

## APPENDIX B

### Comparison of Dust in Boiler Combustion Gases

### Powdered Coal vs. Dust-Catcher Quality Blast Furnace Gas

*Basis.*

Steam
- 1500 Btu per lb

Coal
- 78 per cent boiler efficiency
- 1400 Btu per lb
- 7.5 per cent ash
- 15 lb combustion gases per lb coal
- .08 lb per cu ft density of combustion gases
- 30 per cent excess air.

Blast furnace gas
- 75 per cent boiler efficiency
- (a) 92 Btu per cu ft—thermal value of gas
- (b) 105 Btu per cu ft—thermal value of gas
- 2.5 grain dust per cu ft of blast furnace gas containing 7 per cent carbon (6 per cent combustible carbon)
- 2.4 grains of non-combustible dust per cu ft
- (a) 1.76 cu ft combustion gases per cu ft of 92 Btu gas
- (b) 1.84 cu ft combustion gases per cu ft of 105 Btu gas
- 25 per cent excess air.

| | Coal | Blast furnace gas | |
|---|---|---|---|
| | | 92 Btu | 105 Btu |
| Heat input to boiler per 1000 lb of steam — Btu | 1,925,000 | 2,000,000 | 2,000,000 |
| Fuel fired per 1000 lb of steam — lb ,cu ft | 137 lb | 21,700 | 19,100 |
| Carbon-free ash per 1000 lb of steam — lb | 10.3 | ..... | ..... |
| grains | 72,000 | 51,000 | 45,000 |
| Combustion gases per 1000 lb of steam — cu ft | 25,600 | 38,000 | 35,200 |
| Dust in combustion gases — grains per cu ft | 2.8 | 1.4 | 1.3 |

becoming more and more dependent upon well-conditioned gas for the generation of hot blast. Steel processing would be the less satisfactory technically and economically in many plants if a fairly conditioned blast furnace gas were not available for direct metallurgical use, or for the equivalent release of invaluable coke oven gas. If blast furnace gas were not suitably conditioned for boiler use, the vast quantities of electric power demanded by a steel producing plant would necessitate the transportation, handling and processing of a great mass of coal at a time when the agencies of transport and mechanisms are taxed to the utmost. The potential boiler fuel represented by only 60 per cent of the total blast furnace gas from 200 American blast furnaces is equivalent to at least 1000 cars of coal a day.

This rather lengthy dissertation has attempted to present a picture of blast furnace gas conditioning from a good many angles. We have probed a little at the scientific aspects. We have had a little of its history. We have cited the degrees of cleaning deemed necessary for the varied uses of blast furnace gas, and we have described some of the many devices and accessories for doing the job. We have touched on the economic aspects of the enterprise. We have tried not to "spare the horses" in acknowledging the extent to which our efforts at accomplishing the task fall short of the ideal.

In general, this matter of blast furnace gas conditioning is handled fairly well, but only that. There is room for improvement. We blast furnace people have been inclined to nurse a secret pride in our so-called "rugged practicality", and we have sometimes been inclined to put on a protective front of indifference to scientific matters which we may find burdensome to understand. Perhaps it was Thomas Edison who remarked that the most successful and useful developments were those based upon highly complex scientific phenomena yielding simple results. Such are the automobile, the radio and the plane.

There exists a surprising amount of knowledge concerning minute particles, but it is found in dispersed quarters, inherently strange to us routine blast furnace people. It is found in the laboratories of public health services, of industrial chemists, and of weather bureaus. It would probably contribute substantially toward improving the technique of blast furnace gas conditioning if this knowledge were pooled in order to harness the complex science of microscopic and sub-microscopic particles so as to yield the simple, desired result.

# "12 YEARS SERVICE HAVE PROVED HOW RIGHT WE WERE..

## ..WHEN WE STANDARDIZED ON BUSS *Super Lag* FUSES"

"BACK IN 1930 in an effort to prevent production interruptions caused by fuses blowing needlessly we decided to standardize on BUSS Super-Lag fuses. We now stock sizes from 3 ampere to 400 ampere.

"12 years service have proved how right we were. We have found that the time-lag in these fuses is of material value in preventing fuses from blowing on starting loads or temporary overloads sometimes caused by machines being crowded too much or carelessly handled.

"The fuse design also seems to be unusually effective in preventing poor contact from burning up fuses as well as the clips in our switches and panelboards.

"We feel that BUSS fuses have definitely cut production losses we would otherwise have incurred."

*Neil K. Bangs,* Ch. Elecn.
The Fox Paper Co., Lockland, Ohio.

*"We feel that BUSS fuses have definitely cut production losses we would otherwise have incurred."*

**Avoid shutdowns—save man-hours in your own plant.**

The experience of Mr. Bangs simply proved once more that it is not necessary to suffer useless shutdowns caused by needless openings of

☆ ☆ ☆ ☆

**BUSS SUPER LAG**

protective devices. It shows that once properly installed, BUSS fuses can be forgotten.

They require no maintenance or periodic inspection—as do mechanically operated devices. They don't open needlessly. If one opens you can be sure some condition needs correction. When one opens, it requires less than 45 seconds to renew with an inexpensive link.

**Here is why BUSS fuses greatly reduce or entirely prevent needless blows.**

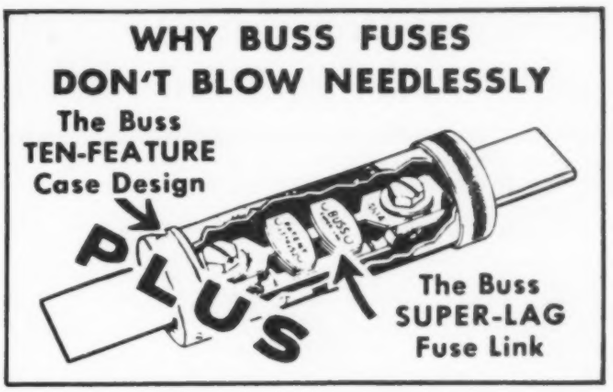
The fuse case is designed to insure good contact on the link, even when the fuse is renewed by an inexperienced person—and it is so designed that vibration or heavy overloads or the constant heating and cooling of the fuse will not permit poor contact to develop. Thus excessive heating which causes fuses to blow needlessly is prevented.

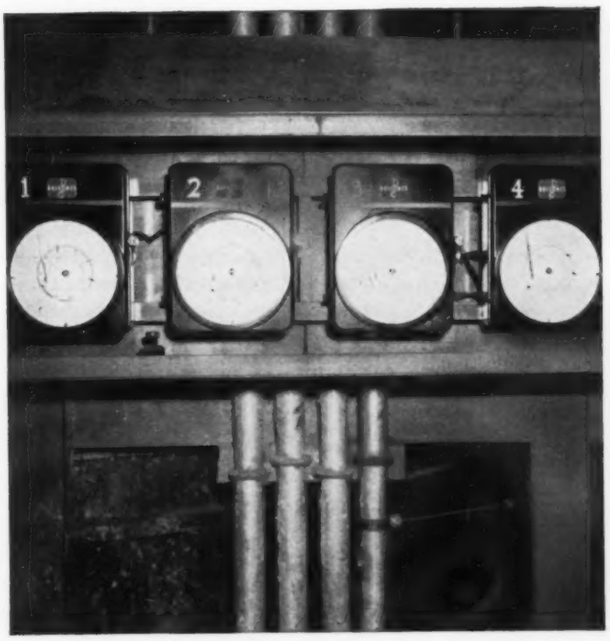
The fuse link used is the famous "BUSS Super-Lag". It has lag plates attached to it. These give it a long time-lag so that unusually heavy starting current or other harmless overloads will not cause the fuse to blow.

**How to solve the "shutdown problem."**

Pass the word along that all purchase records dealing with circuit protective devices should be immediately changed to call for BUSS Super-Lag Renewable fuses. Then, as fuses are replaced or new installations made, your plant will automatically get the benefit of the carefree, trouble-proof protection that BUSS Super-Lag fuses afford.

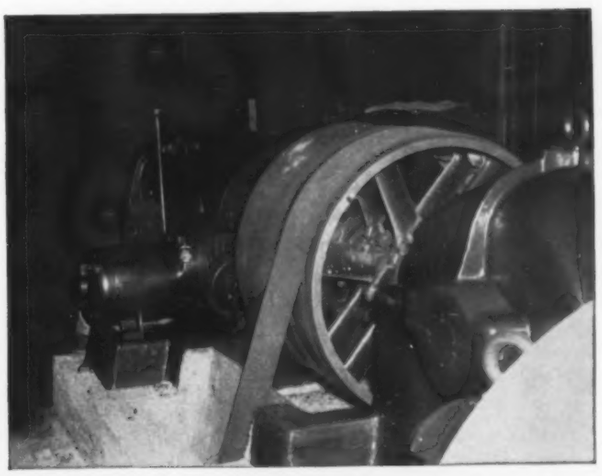
Bussmann Mfg. Co., University at Jefferson
St. Louis, Missouri, Div. McGraw Electric Co.

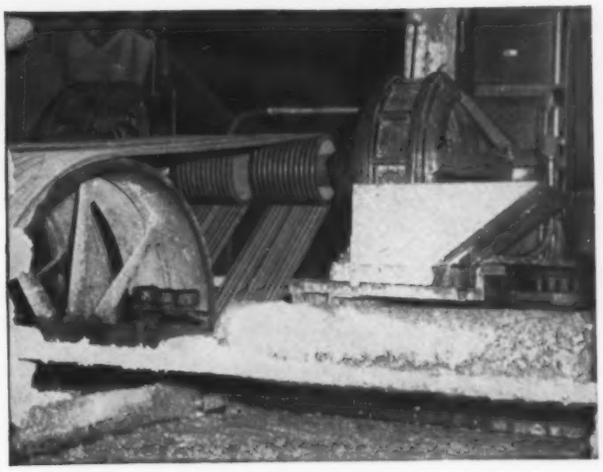


*"We have found that the time-lag in these fuses is of material value in preventing fuses from blowing..."*

# FUSES





## CARNEGIE-ILLINOIS ADDS ELECTRIC FURNACE AT DUQUESNE WORKS AS PART OF 289 MILLION DOLLAR PITTSBURGH PLAN

▲United States Steel Corporation subsidiaries are now engaged in the greatest program of plant expansion in history in the Pittsburgh district. The Pittsburgh program, when completed, will cost $289 million, 66 per cent of which is for the account of the United States Government. U. S. Steel is also engaged in very substantial plant expansion programs in other districts.

It is expected that all of these Pittsburgh projects, which include vast expansions at Homestead, Duquesne and Edgar Thomson Works of Carnegie-Illinois Steel Corporation, will go into operation during the first half of 1943. The first unit of this program was brought in recently when a new electric furnace at Duquesne Works began adding its tonnage of high grade alloy steels to the war effort.

Carnegie-Illinois Steel Corporation since Pearl Harbor has established 187 all-time monthly production records, 60 in its blast furnaces, 34 in the steel producing departments and 93 on rolling mill units.

On five occasions since December 7, 1941, this U. S. Steel subsidiary has broken its over-all monthly blast furnace record for iron production and in each of four months its previous record for steel production was bettered.

Officials of Carnegie-Illinois anticipate that its total production of blast furnace products in the year 1942 will be three-quarters of a million tons higher than in the year 1941, and that its output of steel ingots this year will be more than 750,000 tons higher than last year.

In the month of November, eight new all-time monthly production records were established; three new blast furnace marks being set, and one steel producing shop and four rolling mill units also sharing the honors.

As a result of Carnegie-Illinois' pioneering of steel airplane landing mats, millions of square feet of this material have been produced by various steel fabricating concerns. This company has been gratified to hear of the value of these mats wherever rapidly assembled airfields are necessary on the far flung fighting fronts. In addition, many more millions of square feet of these steel landing mats flying fields are under contract to be produced.

At the Christy Park plant of National Tube Company where a revolutionary method of spinning bombs developed by the company is being used, bombs are flowing from the production line ten times faster than before Pearl Harbor.

Army orders for 1,000,000 anti-air-

**The first of a three-furnace battery of electric furnaces at Duquesne began operation in November.**

craft projectiles were completed 62 days ahead of schedule by the Oil Well Supply Company, a United States Steel subsidiary.

In addition, the Lorain Works of the National Tube Company produced all of the 24-inch pipe for the 550-mile oil pine line between Longview, Texas, and Norris City, Illinois, in only four months. Like every pound of U. S. Steel production today, this pipe was produced for the war effort.

The Ambridge plant of American Bridge Company in the year since Pearl Harbor established its best production record since 1930. This was accomplished, despite the conversion of its activities from standard structural fabricating of steel for skyscrapers and bridges largely to the production of highly specialized products, such as ships, parts for gun mounts, range finders, shells, tanks, cranes, electric furnaces and machine tools.

Directing its activities 100 per cent to the war effort, this Ambridge plant turned out 22 new and complete Heroult electric furnaces with a rated yearly capacity of some 720,000 tons of critical alloy steels for diversified war uses, an all-time record for this particular activity.

Outstanding among the accomplishments of American Bridge Company has been the construction of a fully equipped and completely integrated shipyard for the U. S. Navy on a 64-acre river front site adjoining the Ambridge plant. This yard, operated by American Bridge Company, is now producing the Navy's latest type landing ships for tanks and it is expected that the first unit will be launched within a very short time. Altogether there are eight ships in progressive stages of construction at the new Ambridge yard.

Geared perhaps to the speediest construction schedule of any newly built inland waterway shipyard this $8,500,000 facility was completed in eight months and parts of the yard were actually put into operation 4½ months following the start of the project, at which time the first three keels were laid.

In building the yard and its facilities some 3,500 tons of steel, enough to build two modern Navy destroyers, were conserved by re-use of dismantled, inoperative U. S. Steel structures acquired from other localities.

The H. C. Frick Coke Company and affiliated coal mining subsidiaries

## *WOMEN STUDY SYNTHETIC RUBBER MANUFACTURE*

**These four girls belong to a class which is now studying elementary chemistry and plant operation in order to take a part in the nation's synthetic rubber program. They will work in the Koppers United Company synthetic rubber plant now under construction in the Pittsburgh area if they pass a four-months course with acceptable grades. Classes of several hundred other men and women are being formed. Here Dr. James P. Coull, professor of Chemical Engineering at the University of Pittsburgh, shows the girls how to work a temperature and humidity controlled tray dryer.**

## *FIRST INDIANA COMPANY RECEIVES TWO-STAR FLAG*

**The Army-Navy "E" pennant with two stars, continued recognition for outstanding war production has been awarded Bantam Bearings Corporation here. The Bantam plant is the first in Indiana and one of four in the entire midwest to receive two stars on its banner for its service in war production.**

**The presentation was made by Lieut. Commander Richard Wagner, of the United States Navy's Midshipmen School at the University of Notre Dame. It was received on behalf of the company by R. B. Nichols, vice-president and general manager and Orville Zimmer, president of the Bantam employee's union.**

**In the picture are (left to right) Ensign H. B. Miller, R. B. Nichols, vice-president and general manager, Lieut. Commander Richard Wagner and Orville Zimmer, president of the Bantam C. I. O. local who accepted it on bahalf of the company employees.**

## *ARMY-NAVY "E" TO SEVENTY-SIX YEAR OLD COMPANY*

**Presentation of the Army-Navy "E" to The C. M. Kemp Manufacturing Company took place at the company's plant in Baltimore on November 12th. Seven hundred workers and their families, Army and Navy officers, and State and City Officials attended.**

**The "E" flag was presented by Major Thomas G. Lamphier, Army Air Corps, to W. Wallace Kemp, president of the seventy-six year old concern and son of the founder. Incidentally, Mr. Kemp qualifies as the oldest employee, having served the Company for forty-four years.**

**The "E" pins were accepted by a representative group of employees, comprising J. Elmer DeHaven — forty years service, William Hunt — thirty-six years, and Miss Edna Hanson, who made the acceptance speech, twenty-four years.**

## *WOMEN TAKE OVER ON MANY STEEL PLANT JOBS*

**Mrs. Irene Miller loading a feeding reel for a cutoff machine in the hoop shop, McDonald Works, Youngstown District, Carnegie-Illinois Steel Corporation.**

**In commenting upon female help for a steel plant, Mr. A. C. Cummins, general superintendent, Youngstown District, said, "The employment of women on this operation has proven entirely satisfactory as they are showing a great aptitude for the work they are performing. We have lost many men to the armed forces, and if the present male force is further reduced, it will be necessary to draw upon womanpower to an increasing extent."**

of U. S. Steel in the first ten months of 1942 produced 25,000,000 tons of coal, a tonnage equal to the output for the entire year of 1941 and also of 1940, which in turn had been the best years for coal production since 1929. The entire 1942 output is expected to exceed that of the boom year of 1929.

### TRUCK PERFORMANCE EXCEEDS CLAIMS

▲ Lift Trucks, Incorporated, of Cincinnati, Ohio created and manufacture the HydroLectric, the motorized hand lift truck having rear wheel drive and automotive gear transmission with excess motor and battery power.

Years ago, eight hours' operation a day for electric trucks was considered a fair test, and it was on that basis the first HydroLectrics were tried out. But, performances far exceeded expectations. Actually in a fourteen-day test at a large machine tool plant, the HydroLectric handled average loads of 5000 pounds continuously from twenty to twenty-four hours instead of but eight hours of 3000 pound loads as originally hoped for.

These original HydroLectric trucks are still in operation with records of 12 years on the basis of 8-hour day service.

HydroLectrics are manufactured only at Cincinnati, Ohio by the same Stuebings who created hand lift trucks in 1910.

According to W. C. Stuebing, president of Lift Trucks, Incorporated, HydroLectrics are performing far better than the claims made for them. Mr. Stuebing attributes this unusual performance to correct design, sturdy construction, and above all, thirty years' experience in lift truck engineering and manufacturing.

Mr. Stuebing claims any inexperienced man can operate the HydroLectric. Maximum loads are easily lifted through a powerful hydraulic ram. Then, by pressing the patented finger control, heavy loads are moved forward or backward without effort.

Advantages of the HydroLectric are: Powerful motor — large battery — rear load wheel drive to insure positive traction — four wheel construction for safety and stability — balanced handle — finger tip control — it costs only 9c per day for power — weighs only 1/3 and costs only 1/3 of other power trucks of equal load capacity.

## NON-METALLIC CONTROL PANEL SAVES STEEL

▲ In step with the effort to conserve sheet steel so vital to war needs The Hays Corporation, Michigan City, Indiana announces instrument and control panels made of Masonite reinforced with steel angles. The body of the panel is made of cross grained Masonite $\frac{5}{8}$ inches thick bolted to a framework of 3 x 3 angle steel. Braces of 2 x 2 angle steel reinforce the center of the panel to insure adequate support for the instruments and controllers. The canopy and doors are of cross-grained Masonite $\frac{5}{16}$ inches thick.

Masonite material is exceedingly hard and takes a finish comparable to steel. In order to match the finish standard for Hays steel panels the entire Masonite panel is first gone over with a sanding surfacer after which the priming coat is sprayed on and rubbed down to a smooth base. This is followed by several coats of undercoater, sanded and rubbed. After a thorough drying the finishing coats of black lacquer are sprayed on, giving a velvety finish that retains its beauty indefinitely. The inside is finished with two coats of gray lacquer. After the instruments and controllers are in place, it is practically impossible to distinguish the Masonite panels from the steel panels.

**After proper finishing, the non-metallic panel matches up well with existing steel panels.**

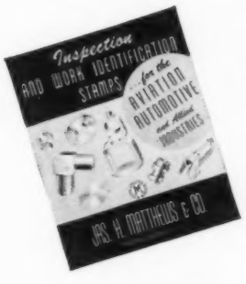
## STRAINERS FOR VARIED SERVICE

▲ According to S. P. Kinney, of S. P. Kinney Engineers, Pittsburgh, the scope of the use of the Brassert Self-Cleaning Water Strainer has been greatly changed. The strainer, made in 3 inches to 30 inches pipe line sizes, is now built of special materials for use in straining sea water, and also for service at coke and similar plants for straining ammoniacal liquor. The strainer removes fine suspended particles from raw or process water, and disposes of these particles in a continuous, automatic and self-cleaning manner. Units now in operation in industrial plants assure a steady flow of clean water from rivers, lakes or wells for plant equipment. Over 350 Brassert strainers are in such plants and on special new uses as mentioned above. The units are also used in various process industries.

The new Brassert self-cleaning water strainers for sea water are equipped with ni-resist cones, chrome-nickel body and covers, admiralty metal ring gear and monel metal


ETCHING STAMPS for CODE MARKING
NOW MADE IN AN
*Amazing New Material*

Results of tests in actual production have shown that Matthews new "S-22" Synthetic outlasts the best rubber or other synthetic stamps from three to four times! The new "S-22" Synthetic is unaffected by acid etching inks.

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liners, stellite bushing and sleeve, stainless steel main shaft and pinion gear, and stainless steel retainer rings for stainless or porcelain straining media.

Brassert strainers for ammoniacal liquor are equipped with chrome-nickel body, cover and revolving drum castings, forged steel ring gear, stellite bushing and stainless pinion gear, stainless steel liners, stainless steel retainer rings for stainless steel or porcelain straining media.

Strainers for use on river, lake, canal, or well water are equipped with the same chrome-nickel body, cover and drum castings, stellite bushing and stainless steel pinion. Bronze is used for the ring gear, the liners, and the straining media retaining rings. The straining media is of porcelain or stainless steel conical screens.

The Brassert automatic self-cleaning strainer consists essentially of a slowly rotating conical drum, mounted on a vertical shaft, within a cast iron housing. The entire surface of the drum is drilled to receive the straining media which consists of porcelain discs, or flat, or conical wire stainless steel screens.

The dirty water, or other liquid to be strained, enters through an inlet at the bottom of the housing and then rises around the outside of a revolving drum. The discharge of the clean water is effected through an outlet at the bottom of the housing; this discharge being diametrically opposite the inlet. The dirty water entering the strainer is under pressure and therefore passes through the straining elements in the drum. The foreign matter in the water is retained on the surface of the perforated porcelain discs, or screens, and is carried in this position, by slow rotation of the drum, to a backwash slot. One or two washout orifices are cast integrally with the housing, according to the size of the strainer. These orifices provide a slot which serves as a washout discharge for one vertical row of screening media. At this slot a reversal of flow takes place, and clean water from the inside of the drum flushes through the screening media and removes the dirt from the strainer.

Differential pressure, between the water in the interior of the drum, and atmospheric pressure provides an efficient means for backwashing the straining media. The pressure drop through the strainer is 1½ pounds, and the backwash water is discharged at atmospheric pressure.

The strainer is available for use with 3 inches to 30 inches pipe line sizes and for straining from 100 to 32,000 gallons per minute. Further details may be secured by writing S. P. Kinney Engineers, 233 Oliver Avenue, Pittsburgh, Pennsylvania, exclusive sales engineers for Brassert strainers and other Brassert specialties.

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FURNACE AND OVEN DOORS
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INDUSTRIAL LOADS...
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Takes the IF out of LIFT!
ENGINEERED FJR EQUIPMENT
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LOCATED IN A PHILA. SUBURB . . . WYNCOTE, PA.


## CRANE DOES TWO DAYS WORK IN ONE HOUR

▲ Amazing as it sounds that is the actual experience recently reported by a southern metal products plant after installing a three-ton overhead traveling crane. An official of the company said that now three men handle as much loading and unloading in one hour as four men formerly did with other methods in two days.

The crane, a P&H Trav-Lift 3-motor, double-I-beam type, is cage operated and equipped with variable speed control. It has a span of 47 ft 8 in., a lift of 18 ft, and travels the full length of the plant's receiving and shipping bay.

Cranes of this type are contributing a great deal toward speeding production of war materials. The results of the installation discussed here are typical in the savings of time and man

power they make possible. The Harnischfeger Corporation, Milwaukee, long-time manufacturers of overhead materials handling equipment, is now producing these cranes in the biggest quantity of all its history. With capacities up to 15 tons, Trav-Lifts are suitable for smaller manufacturing plants and in various sections of larger plants requiring either constant or intermittent crane service for lifting, lowering and moving loads within 15 tons over definite areas. They provide all the advantages of overhead materials handling — combined with the obvious economy over larger cranes with unnecessarily high capacities.

### STEEL EMPLOYEES BOOST BOND SALES

▲ Employees of Carnegie-Illinois Steel Corporation are buying war bonds at the rate of more than one million dollars a month.

In making the announcement, Mr. Perry, president of this U. S. Steel subsidiary, said, "We are proud of the manner in which the employees of Carnegie-Illinois, who have distinguished themselves for record-breaking steel production, have met this particular challenge. We are fast approaching our goal which is 100 per cent participation and are striving for at least 10 per cent of our individual earnings."

### SHELL MANUFACTURE PROGRESSES AT T. C. I.

▲ The workmen in the shell forging plants of the Tennessee Coal, Iron and Railroad Company at Ensley recently delivered to the United States Army Ordnance Department the millionth 155 mm., as well as the millionth 75 mm. shell forging. The presentation was made during a visit to the plants by army ordnance and company officials.

The plant making the 75 mm. shell forgings was developed from a pilot plant and delivered the first forging on August 1, 1941. The millionth shell to pass final inspection there came through at 4:00 a.m. on December 14, 1942.

The 155 mm. shell forging plant delivered its first shell forging on November 20 (Thanksgiving Day), 1941 and came through with the millionth shell forging at 10:00 p.m. on December 15, 1942, only a few hours behind the record of the 75 mm. plant.

Robert Gregg, president of the company, and some of the plant management officials, accompanied by Col. E. C. Bomar and members of his staff, were at the plants recently and the shell forgings were presented to Col. Bomar on behalf of the company and the workers by Messrs. Edward M. Streit and Andrew J. Patrick, Jr., turn foremen of the two plants.

Mr. Gregg stated, "this is further proof that given a job to do we can and will do it."

### U. S. STEEL SUBSIDIARY CHANGES NAME

▲ The name of Scully Steel Products Company, United States Steel Corporation Subsidiary, will be changed to United States Steel Supply Company, effective January 1, 1943. E. E. Aldous, president, announced that

HAYS
GAS-AIR
RATIO CONTROLLER

*Automatic*
COMBUSTION CONTROL
*for* SOAKING PITS
SLAB HEATING, RE-HEATING FURNACES, ETC.

**PRESSURE CONTROL—control of heat input or complete combustion control are offered by HAYS to help produce MORE steel, BETTER steel at lower cost. Hays engineers are at your disposal in securing quick action in applying partial or complete control as your need demands. Get in touch with the nearest Hays representative or write the factory direct.**

***For Oil Fired Furnaces—Publication 42-527***
***For Gas Fired Furnaces—Publication 42-526***
***For Pressure Control—Publication 42-530***

The HAYS CORPORATION
COMBUSTION INSTRUMENTS AND CONTROL
MICHIGAN CITY, INDIANA, U.S.A.

the new name will not involve any change in the management or the business in which Scully Steel Products Company has been engaged. The principal reason for the change is to identify the supply company more closely with other subsidiaries of United States Steel Corporation.

General headquarters of the United States Steel Supply Company are located at Chicago. Warehouses are operated at the following locations: Balitmore, Boston, Chicago, Cleveland, Newark, Pittsburgh, St. Louis and St. Paul. These warehouses under normal conditions are suppliers of a widely diversified line of rolled steel products and related items.

### ELECTRIC HEATERS FOR ISOLATED SPOTS

▲ Forced-convection heaters are materially contributing this winter to the health, comfort and efficiency of engineers in the cabs of electric locomotives, guards in towers, and watchmen's houses around industrial plants. The heaters are also being increasingly used in shipyards, hangars, substations, warehouses, crane cabs, and similar out-of-the-way places, the General Electric Company reports.

Controlled automatically, and rated from 2 to 15 kw, General Electric heaters are available in the suspension type for wall and ceiling mounting. The portable type, which while intended primarily for floor mounting, is readily adaptable for either wall or ceiling use. The heaters are sturdy, economical in operation, and easily and quickly installed, since it is only necessary to connect them to the nearest outlet.

In the case of industrial plants, they effect further economies by eliminating the installation and maintenance of costly steam piping to remote points about the plant, as well as the heat losses from such pipe lines.

### DRIVE CONTROL STEPS UP SPEED RANGE

▲ For use where wide speed range or close regulation is required, the Rototrol, a versatile d-c drive control, is described in a new booklet by Westinghouse Electric and Manufacturing Company.

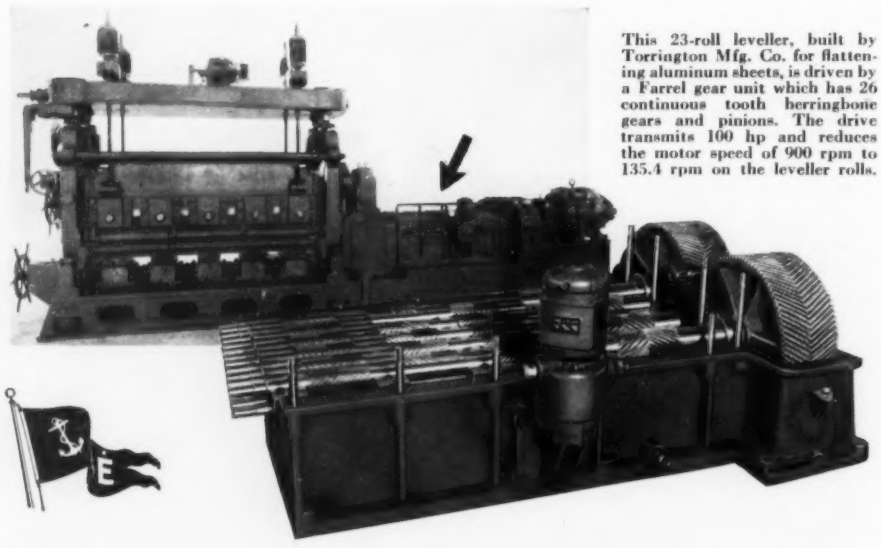
The new 14-page booklet "A Challenge to Designers of Drive Control" describes how Rototrol increases the speed range; keeps the speed of a direct-current motor constant regardless of load variations; makes accurate or very close speed regulation possible; gives uniform acceleration and deceleration; and maintains constant horsepower and uniform tension.

### LITERATURE AVAILABLE

▲ "Calling All Horsepower," a program designed to save critical war materials and to get maximum production out of every motor, is announced in a new 20-page booklet by Westinghouse Electric and Manufacturing Company.

Undertaken at the suggestion of the War Production Board, the "Calling All Horsepower" program points out how motor overload capacity can be used to get more production from every available unit of horsepower, and at the same time effect huge savings in critical materials.

Six wartime application recommendations are listed and discussed. Accompanying charts and illustrations give specific information on

This 23-roll leveller, built by Torrington Mfg. Co. for flattening aluminum sheets, is driven by a Farrel gear unit which has 26 continuous tooth herringbone gears and pinions. The drive transmits 100 hp and reduces the motor speed of 900 rpm to 135.4 rpm on the leveller rolls.

## FARREL-SYKES HERRINGBONE GEARS
## Transmit Most Power in Least Space

The requirements for driving this 23-roll aluminum sheet leveller dictated a unit in which the pinions could be nested closely in order to connect the output shafts with the small diameter, closely-spaced leveller rolls. Six years of trouble-free performance have proved Farrel-Sykes continuous tooth herringbone gears and pinions to be admirably suited to this application.

Continuous tooth gears have a greater effective face width and a greater number of teeth in contact, giving them extra strength and extra bearing surface for high load-carrying capacity in small space.

The opposed helices balance and absorb axial thrust within the gear member, preventing harmful thrust loads and resultant stresses on other parts of the drive, without the need for space-consuming thrust bearings.

These and other inherent advantages of Farrel-Sykes gears account for their long-lived, economical and efficient performance in all types of drives, which make them the choice of engineers for critical applications.

We make gears and gear units for every type of service and offer the services of an experienced engineering staff for consultation on gear problems.

FARREL SYKES GEARS
FARREL-BIRMINGHAM COMPANY, Inc.
ANSONIA, CONN. - - - - - BUFFALO, N. Y.
*The Gear with a Backbone*

pounds of war material which can be saved by each method. Recommendations are to take advantage of overload service factors built into motors, plus favorable temperature conditions; to take advantage of favorable voltage and frequency conditions; to use standard open sleeve-bearing motors in place of fan-cooled or splash-proof motors wherever conditions permit; to use highest speed motors permitted by application; to substitute a-c motors wherever possible; and to match control to motor on the basis of horsepower rating.

A copy of booklet B-3188 may be secured from department 7-N-20, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania.

▲ A new booklet on NE (National Emergency) Steels has just been published by Joseph T. Ryerson & Son, Incorporated. Alloy steel users will welcome this practical, simplified data book which deals with the selection and heat treating of NE Steels. Typical of all Ryerson service literature, it is readily understandable and explains the subject of NE Steels minus the confusion of curves, graphs and technical wordage. Copies are available on request.

The Jominy end quench hardenability test, a quick method of determining the heat treatment response, is carefully explained step by step and a cut-away diagram shows the test in action. Because the Jominy test is the simplest and quickest way of determining hardenability, The Technical Committee of the American Iron & Steel Institute adopted it as the standard for testing NE steels. This test is easy to make and accurate, but the interpretation of the test results has, heretofore, been more or less of a mystery to many steel users.

The booklet includes four tables for coverting Jominy test results into tensile strength, yield point, elongation, reduction of area, etc. One table indicates the cooling rate at various distances from the quenched end of a Jominy test sample. Another table gives the cooling rates at center, half radius and surface for 1 inch, 2 inch, and 3 inch round bars quenched in oil and water. A third table shows the approximate relationship of physical properties to hardenability. The last table gives the approximate relationship between drawing temperatures and tensile strength.

The various NE Steels are listed as suggested alternates for standard compositions in the carburizing, medium hardening and high hardening groups. The booklet also shows average physical properties after heat treating together with forging, normalizing, annealing and quenching temperature for thirty of the most widely used NE steels. Available stock sizes in the various NE analyses both hot and cold rolled are also given.

Since the beginning of the NE alloy steel program, Ryerson has been working in every way to encourage industry to switch to the "lean" alloy compositions in order to promote the conservation of critical alloying elements. Hundreds of tests on NE steels have been made in the Ryerson laboratory in developing data to assist in the proper application and treatment of the new NE Steels. The Ryerson laboratory has also proved invaluable for speeding deliveries of steels that must be tested to demon-

*From smallest Rod Mill to largest Blooming Mill*

"LIGNALLOY" bearings are fully moulded of special compositions, without laminations, to render the most practicable and most economical service . . . Why not consult us regarding your difficult roll neck bearing problems?

**K. W. ATWATER • ENGINEERING**

INVESTMENT BUILDING • PITTSBURGH, PA.

Representatives in Pittsburgh, Pa., Chicago, Ill., Middletown, Ohio and Johnstown, Pa.

strate their ability to meet various government specifications. Additional heat treating and testing equipment is constantly being added to keep pace with the demand for steels of accurately known physical properties. Much of the information and experience gained in the Ryerson Laboratory has not only been helpful to customers but has contributed to the new Ryerson NE steel booklet.

▲ Valuable hints on the care of storage batteries, whether in industrial use or in automotive service, are given in the current issue of the industrial edition of Exide News, under the heading of "The Great Devourer." Free copies are available to plant executives, maintenance men, and others who are interested. Address: The Electric Storage Battery Company, 19th Street and Allegheny Avenue, Philadelphia, Pennsylvania.

▲ Hundreds of manufacturers of products fabricated from thin metals will receive surprisingly simple and encouraging answers to their wartime welding problems in the dramatic pages of a new book, "Weld Thin Metals," just released by Allis-Chalmers.

Offering the company's new Weld-O-Tron as an important industrial weapon now ready to handle tough welding assignments of all kinds, the bulletin illustrates successful applications throughout industry, as well as for the Navy, Army and Air Corps. Applications in the ship-building and aircraft industries are especially pointed out.

Metals as thin as 32 gauge — aluminum, stainless steel, mild metal, monel, inconel, nickel, galvanized iron, terne plate, castings, copper, bronze, brass and lead — all can be welded by the Weld-O-Tron, according to the bulletin. Basic questions and answers about thin metal welding form an important feature of the new catalog.

In addition to offering the bulletin, B 6049A, free, Allis-Chalmers invites fabricators to send samples of its materials to its welding research laboratory.

▲ A new, twenty-four page picture book, "Whiting Products for Industry" just published by Whiting Corporation, Harvey, Illinois, gives a comprehensive picture of Whiting's service to industry with condensed, but pertinent facts on its varied product lines, including cranes, railroad and aviation equipment, cupolas and foundry equipment, quick-work products, Swenson evaporators and filters, and other special Whiting equipment for heavy industries.

All interested persons will be sent a copy of this new book, "Whiting Products for Industry" (Book No. 236), upon request.

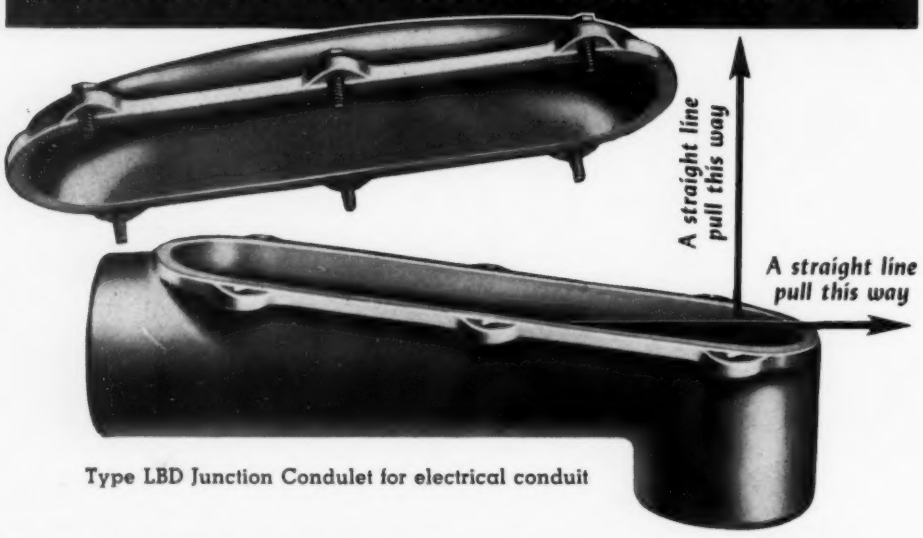
▲ The Trumbull Electric Manufacturing Company of Plainville, Connecticut has made available a compact unit distribution panel-board in drip-proof cabinet, having shock-proof fuse clamps for marine applications, such as for lighting, power, intercommunicating systems and radio.

It is available in 6 to 20 circuits. The panel is made of bakelite sections mounted on channel iron rails — service 2/2 wire 125 or 250 volts. Box and cover of code gauge steel having priming coat of zinc chromate and finish coat of gray lacquer. Trumbull solderless connectors furnished in the mains.

These are described and listed on Data Sheets MAR-1 and MAR-1L.


**CROUSE-HINDS**

Originator of the double duty, **straight line pull** type of junction **Condulet** that saves time and critical material.




Type LBD Junction Condulet for electrical conduit

- **A straight line pull** through either hub. Does double duty.
- **Unobstructed pulling space.** Prevents damage to conductors.
- **Domed cover.** Provides extra space for easy bend in conductors.
- **Gaskets** can be furnished. They make the condulet vaportight and raintight.
- **13 sizes.** For ½ inch to 6 inch conduit.
- An **Explosion-proof** type available. Type LBH in 8 sizes, ½ inch to 3 inch.

Type LBD Junction Condulets



Type LBH Explosion Proof and Dust-tight Junction Condulet

A Nationwide Distribution Through Electrical Wholesalers

**CONDULETS**—manufactured only by

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SYRACUSE, N. Y., U. S. A.

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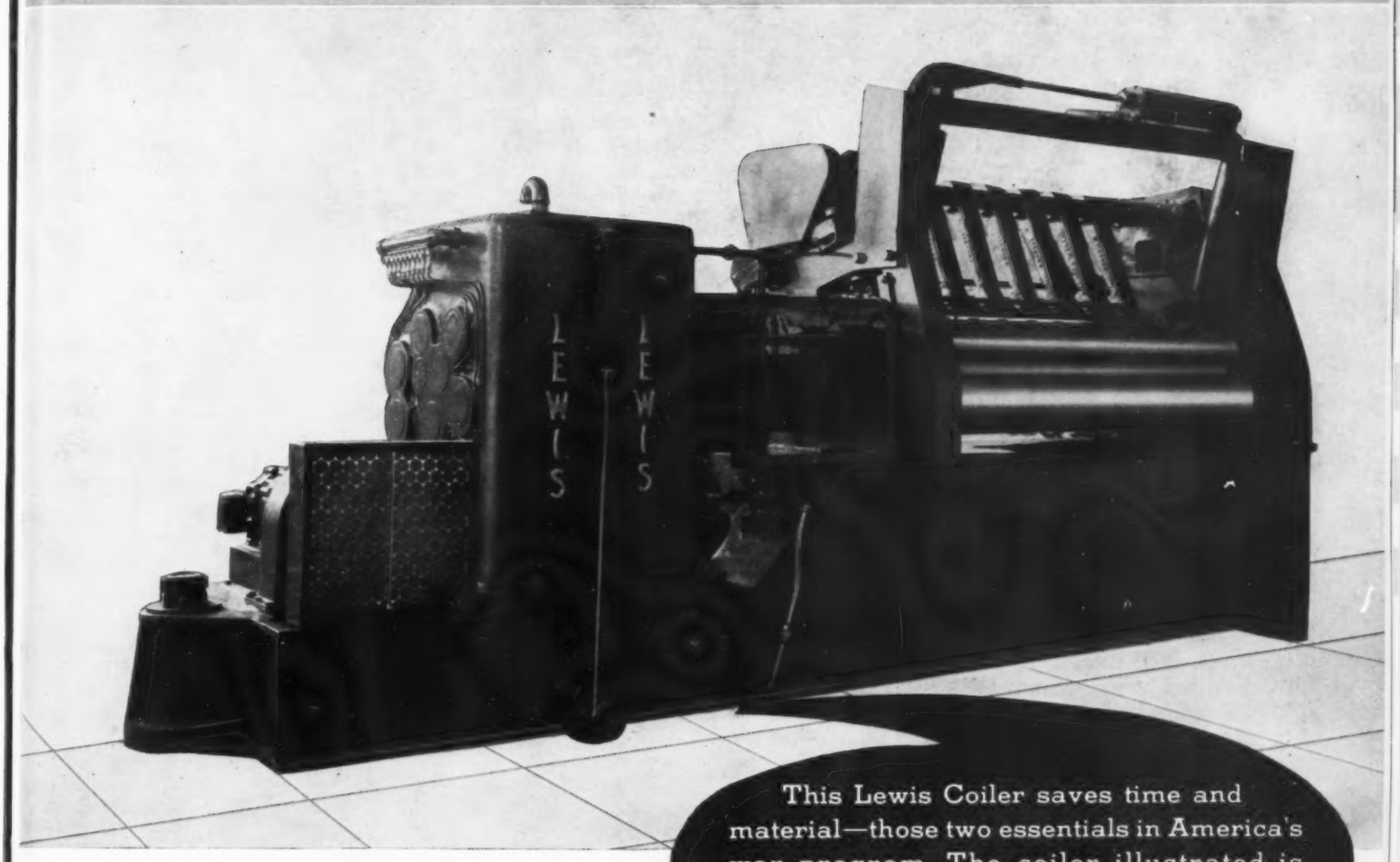
*Resident Salesmen:* Albany — Atlanta — Baltimore — Buffalo — Charlotte — New Orleans

CROUSE-HINDS COMPANY OF CANADA, LTD. *Main Office and Plant:* TORONTO, ONT.

# New LEWIS Strip Coiler

## ELIMINATES DANGER OF SCRATCHING




This Lewis Coiler saves time and material—those two essentials in America's war program. The coiler illustrated is being used to coil aluminum strip, which if scratched, is useless for many important purposes.

### *Features of the Lewis Three Roll Coiler:*

Designed for coiling steel or non-ferrous strip up to 72" wide.

Coiler is equipped with guides, strippers and fibre lined pneumatic roller kick-off arms all especially designed to prevent scratching or other defacement of the material.

Steel forming and pinch rollers are hardened and ground. Top forming roller is equipped for individual or simultaneous adjustment on both sides through hand wheel and worm and worm gear. The machine is also equipped with side aligning rollers to keep the rotating coil straight at all times and has pneumatic simultaneous side adjustment through racks and pinions for widths from 24" to 72".

The machine is designed to swing in a semi-circle away from the mill or out of the strip line as may be required and is arranged with locking features to hold the unit in position. It can also be converted into a portable unit if desired.

LEWIS ROLLS step up tonnage

**LEWIS FOUNDRY & MACHINE**

DIVISION OF BLAW-KNOX CO.

PITTSBURGH, PA.

# ITEMS OF INTEREST

**C. R. Dobson** has been appointed chief industrial engineer for the Jones and Laughlin Steel Corporation, under the vice president in charge of operations, S. S. Marshall, Jr. He succeeds Lauson Stone who has resigned. Mr. Dobson started with Jones and Laughlin in their South Side works in 1920 upon his graduation

C. R. DOBSON

from the Carnegie Institute of Technology as an industrial engineer. Since 1930 he has been assistant to Mr. Stone.

**Charles L. Huston Jr.,** director of personnel relations of Lukens Steel Company, Coatesville, Pennsylvania, and a member of the company's board of directors, has been appointed assistant to the president of the company. Mr. Huston joined Lukens as director of personnel relations in September, 1939, after serving ten years with the American Rolling Mill Company, Middletown, Ohio.

**W. L. Buchanan** has been appointed as field manager of renewal parts sales, of the Crocker-Wheeler Electric Manufacturing Company, with headquarters in the Chicago office. Mr. Buchanan's duties will consist of heading up all renewal parts sales and service in the field in line with Crocker-Wheeler's recently established policy of rendering the best possible service on renewal parts orders as well as on new equipment.

Following Mr. Buchanan's graduation from Mississippi State College in 1917 with a degree in electrical engineering, and a major in mechanical engineering, he entered the Westinghouse apprenticeship course where he did test work followed by service engineering work in the Chicago area, and automatic sub-station installation work. He also served as assistant electrical superintendent in the service department, the St. Louis district, and assistant sales manager in the Kansas City office of that company.

In 1933 he was appointed appraisal engineer of the Missouri Public Service Commission and subsequently returned to Westinghouse as installation engineer of automatic substations for the IRT, New York, following which he became interested in steel mill work and supervised the installation of electrical equipment on the hot strip mill of the Bethlehem Steel Corporation at Sparrows Point, Maryland. Mr. Buchanan has also been associated at various times with the Mesta Machine Company, United Engineering and Foundry Corporation, Republic Steel Company, Otis Steel Company, Youngstown Sheet and Tube Company, and more recently with Carnegie-Illinois Steel Corporation as maintenance engineer and subsequently as chief test engineer of the Gary Works.

**Cecil W. Guyatt,** formerly assistant chief industrial engineer of the American Steel and Wire Company, Cleveland, Ohio, has been named chief industrial engineer. **John S. Conant** has been made priorities administrator, at the same time continuing as general supervisor of production planning. **Lloyd W. Hackley,** formerly supervisor of production planning in the cold rolled department at the Cuyahoga Works in Cleveland, has been appointed assistant general supervisor of production planning for the entire company.

**Homer H. Wagner** has been appointed chief electrical engineer of Pennsylvania Transformer Company. He first came with the company as a design and development engineer and won promotions to electrical engineer and now chief electrical engineer.

Mr. Wagner graduated from Culver-Stockton College, with a B.A. in mathematics. He received his bachelor of science degree in electrical engineering at the University of Illinois, and his masters degree in electrical engineering at the University of Pittsburgh.

After working at Westinghouse as a power transformer designer from 1927 to 1930, he was employed,

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United States and entered the employ of Pennsylvania Transformer Company in 1936, as development and research engineer.

H. D. SALTON

**A. G. Bishop,** roll engineer, Republic Steel Corporation, Cleveland, has retired after 43 years with Republic and its predecessor company, Republic Iron and Steel Company. He will live in New London, Ohio. Mr. Bishop joined Republic Iron and Steel Company, in 1899 as a roll designer. In 1932 be became assistant to Carl Meyers, now Republic's district manager in the Canton-Massillon district, who was then roll engineer, and in 1935 went to Massillon with Mr. Meyers. Four years later Mr. Bishop was transferred to Cleveland, Ohio.

**Philip M. Morgan,** president, Morgan Construction Company, Worcester, Massachusetts, and **David G. Baird,** vice president, Marsh and McLennen, have been elected additional directors of Wickwire Spencer Steel Company, New York.

**Forrest Nagler,** chief mechanical engineer, Allis-Chalmers Manufacturing Company, Milwaukee, Wisconsin, has been placed in charge of the company's engineering and development department, succeeding Edwin H. Brown, who has been granted leave of absence to serve as assistant chief, Iron and Steel Division, in charge of the plant facilities section, War Production Board, Washington.

**George B. Wadlow,** for more than 25 years connected with the Continental Roll and Steel Foundry Company, East Chicago, Indiana, in purchasing, production and sales capacities, has been made assistant to the president of the Continental Ordnance Corporation, the recently organized $50,000,000 subsidiary of the company.

**Martin A. Hotham** has been appointed production engineer of the Follansbee Steel Corporation, Follansbee, West Virginia. Mr. Hotham has spent his entire career in the steel industry, going to Follansbee from the American Tube and Stamping Company, Bridgeport, where he supervised steel production and open hearth operations.

**Col. Karl Landgrebe,** for many years vice president of the Tennessee Coal, Iron and Railroad Company, has been appointed vice president of Goslin-Birmingham Manufacturing Company, Birmingham, Alabama.

COL. KARL LANDGREBE

**Arthur V. Wiebel,** who has served as executive consultant to the steel division of the War Production Board for the past year, has resigned to return to his position as assistant vice president of the United States Steel Corporation of Delaware, it was announced recently by H. G. Batcheller, director of the division.

Mr. Wiebel has served as a member of the production directive committee of the steel division, and has been active in the planning of the steel expansion program. In resuming his duties with U. S. Steel, he will devote his time primarily to the expansion program of that company.

**Jerome R. George,** designer and constructer of steel mills throughout this country and in England, France, Belgium and India, a former vice-president and chief engineer of the Morgan Construction Company, Worcester, Massachusetts, and president and chairman of the board of Aetna-Standard Engineering Company, Youngstown, Ohio, died November 30, in Beverly Hills, California. In 1907 he designed and built the first continuous sheet bar mill, installing it at Youngstown Sheet and Tube Company's Campbell plant. Just before his retirement from the Worcester company he supervised the design and construction of the Ford River Rouge plant. Mr. George was 75 years old.

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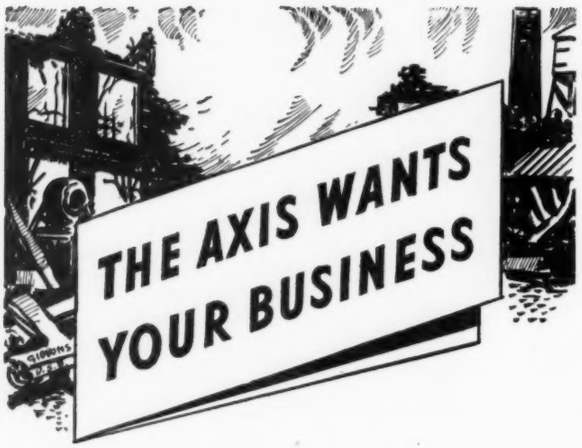


THIS is more than a war of mechanical monsters clashing in the night . . . more than a war of production.

It is a war for markets—*your* markets! The Axis wants your business—wants to destroy it for once and all.

With so much at stake, there is no doubt you will want to do everything you can to meet this Axis threat. Two ways are open: Speed production and BUY BONDS. The only answer to enemy tanks and planes is *more* American tanks and planes—and your regular, month-by-month purchases of Defense Bonds will help supply them. Buy now *and keep buying.*

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When you install the Pay-Roll Savings Plan (approved by organized labor), you not only perform a service for your country but for your *employees.* Simple to install, the Plan provides for regular purchases of Defense Bonds through voluntary pay roll allotments.

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# A. I. S. E.

# DISTRICT MEETINGS

▲

## *Chicago, January 5 . . .*

"Supervisory Control of Steel Mill Power Systems", by W. A. Derr, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania.

## *Philadelphia, January 9. . .*

"The Application of Mercury Arc Rectifiers in Steel Mills by A. D. Howry, Electrical Engineer, Alan Wood Steel Company, Conshohocken, Pennsylvania.

"Electronic Control for Steel Mill Auxiliaries," by J. H. Hopper, General Electric Company, Schenectady, New York.

## *Pittsburgh, January 11 . . .*

"Arc Furnace Control," by T. B. Montgomery, Allis-Chalmers Manufacturing Company, Milwaukee, Wisconsin.

"The English Steel Industry at War," by J. C. Murray, assistant general superintendent, Jones and Laughlin Steel Corporation, Pittsburgh, Pennsylvania.

## *Detroit, Janury 12 . . .*

"Conservation of Materials," by L. A. Umansky, General Electric Company, Schenectady, New York.

# INDUSTRIAL EXECUTIVES!

## THE SCRAP FROM YOUR PLANTS IS NEEDED AT ONCE TO KEEP WAR PRODUCTION MOVING!

YOU know that all our furnaces and mills must be kept working at top speed to win this war. Yet the steel industry, already producing record quantities, cannot attain its full, needed war-time capacity of 90,000,000 tons unless 6,000,000 additional tons of scrap steel is uncovered promptly.

*This critical situation can be solved only by the patriotic cooperation of every American manufacturer.*

In your plant, lying around in repair shops and storerooms, is the scrap America needs to give our boys the fighting tools they must have to win . . .

Broken castings, pipe, obsolete machinery, abandoned line shafting, pulleys, pumps, old boilers, storage tanks, beams, rails, fencing, track, chains, cable, rusty bolts, nuts, and rivets . . .

Round them up and get them moving to the front!

. . . Like the gas appliance manufacturer who searched his plant and found 90 tons of scrap metals . . . or the paper mill that "mined" 1,800 tons of steel from its plants . . . or the rubber company that asked its foremen to "stop holding things" and collected 1,608 tons of iron and steel from old molds and obsolete machinery in a single week!

What others have done, you can duplicate. Walk through your plant with "Scrap" in your mind—you'll be amazed at the harvest. But get it into the fight, *at once* . . . the war won't wait!

★ ★ ★

**HERE'S WHAT TO DO...** Appoint one man as Salvage Manager for your organization. Give him authority to *act*—to condemn old equipment, to move material, to collect scrap of all kinds. Have him separate all scrap by type. Then move it promptly through your regular scrap dealers. Don't wait — start rounding up scrap *now* — and keep your scrap moving until the war is won!

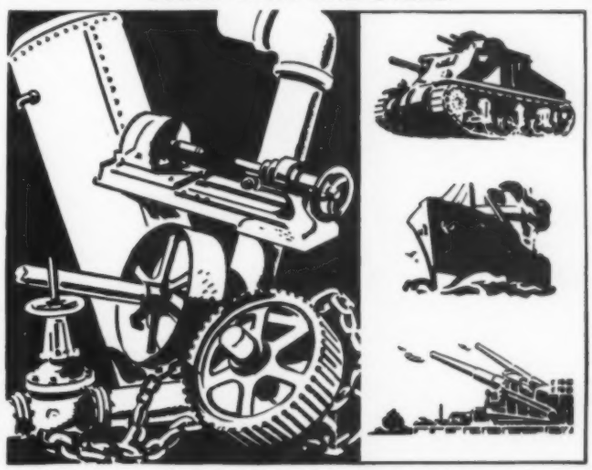
THROW YOUR SCRAP INTO THE FIGHT!

**DONALD M. NELSON says to all industry:**

"The shortage of scrap materials for war production is acute. 6,000,000 extra tons of scrap iron and steel alone are needed this year, and vast quantities of rubber, copper, brass, tin, lead and zinc. Without your immediate, active cooperation — whether you have war work or not—we cannot lick this problem. We urge you to organize at once an all-out collection drive in your plants for these materials."

## SCRAP NEEDED FOR WAR

**SCRAP IRON AND STEEL**



50% of every tank, ship, and gun is made of scrap iron and steel!

**Other metals—Rubber—Rags—Manila rope—Burlap bags**

Thousands of tons of these materials are needed to make bombs, tires for jeeps, surgical supplies for military hospitals, wiping rags for guns, insulation for electric wiring, parachute flares and sandbags.

This message approved by Conservation Division

**WAR PRODUCTION BOARD**

This advertisement paid for by the American Industries Salvage Committee (representing and with funds provided by groups of leading industrial concerns).

**TO EXECUTIVES:**

# NOW YOU CAN HELP

## *Even More...*

**New Treasury Ruling Permits Purchases UP TO $100,000, in any Calendar Year, of Series F and G WAR BONDS!**

The Treasury's decision to increase the limitations on the F and G Bonds resulted from numerous requests by purchasers who asked the opportunity to put more money into the war program.

This is not a new Bond issue and not a new series of War Bonds. Thousands of individuals, corporations, labor unions, and other organizations have this year already purchased $50,000 of Series F and G Bonds, the old limit. Under the new regulations, however, these Bond holders will be permitted to make additional purchases of $50,000 in the remaining months of the year. The new limitation on holdings of $100,000 in any one calendar year in either Series F or G, or in both series combined, is on the cost price, not on the maturity value.

Series F and G Bonds are intended primarily for larger investors and may be registered in the names of fiduciaries, corporations, labor unions and other groups, as well as in the names of individuals.

The Series F Bond is a 12-year appreciation Bond, issued on a discount basis at 74 percent of maturity value. If held to maturity, 12 years from the date of issue, the Bond draws interest equivalent to 2.53 percent a year; computed on the purchase price, compounded semiannually.

The Series G Bond is a 12-year current income Bond issued at par, and draws interest of 2.5 percent a year, paid semiannually by Treasury check.

Don't delay—your "fighting dollars" are needed *now.* Your bank or post office has full details.

Save With . . .

# War Savings Bonds

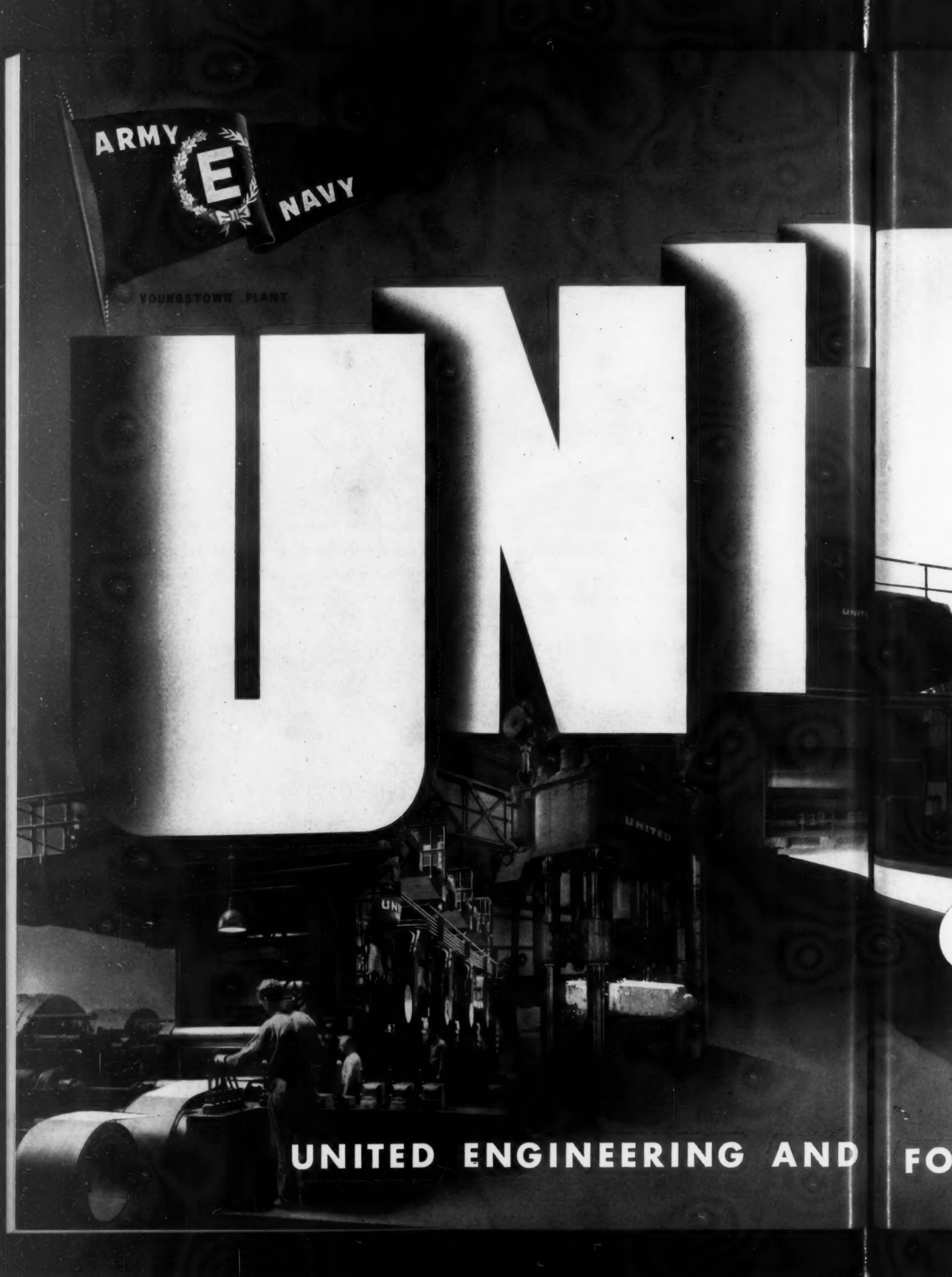
This space is a contribution to America's All-Out War Program by Iron and Steel Engineer

## Sure I'm busy... fighting a War!

"You know, a fellow standing here in my shoes gets a pretty good idea of what this U. S. A. can do when it starts rollin'. I run the flying shear on a four-strand Morgan Roughing Mill . . . Sure I'm busy, fighting a war! And we're going to win it, too! We've got the men and the machines, and the brains . . . LET'S USE 'EM!"

M-109

## MORGAN CONSTRUCTION COMPANY • WORCESTER, MASS.


ARMY
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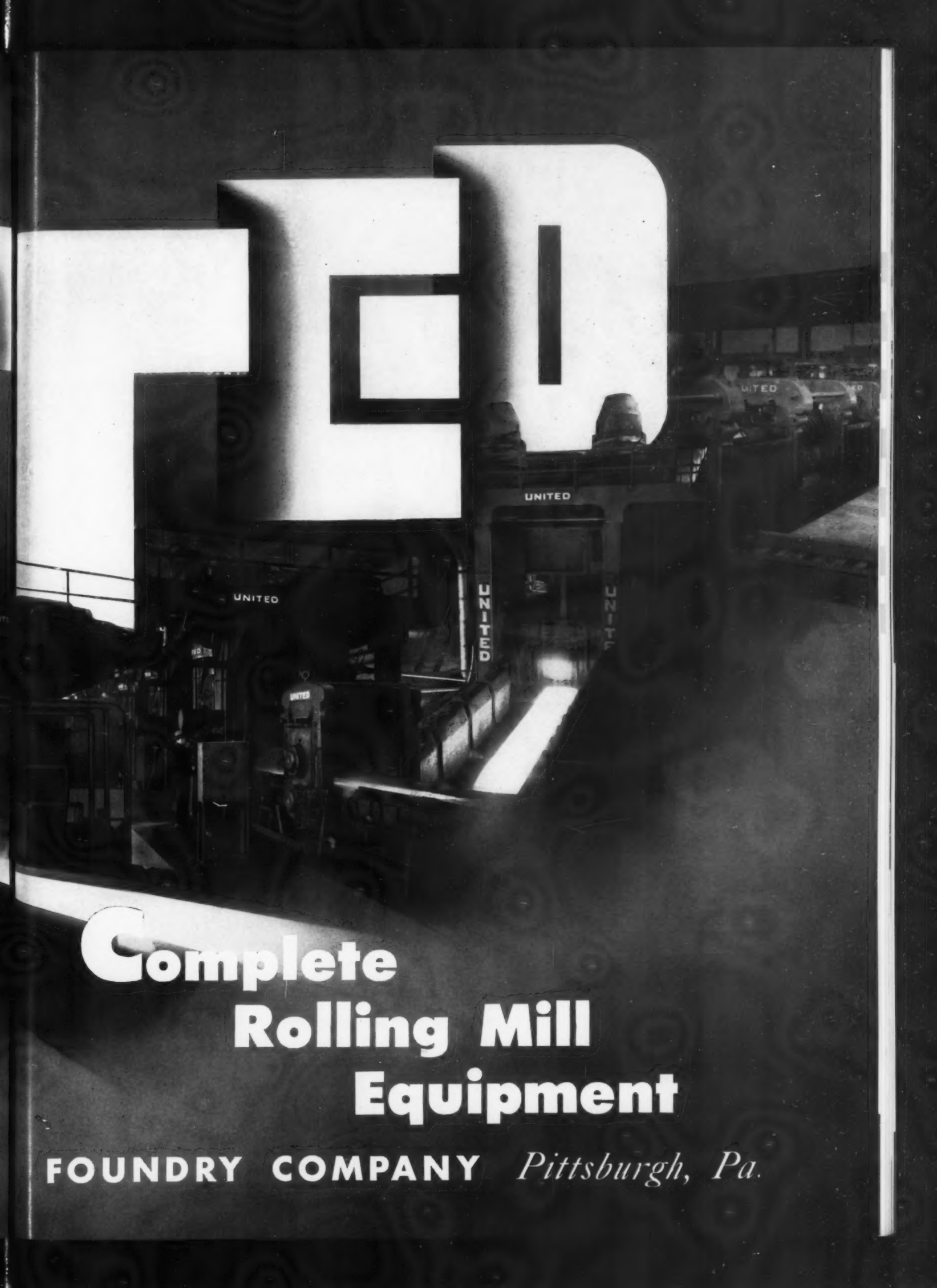


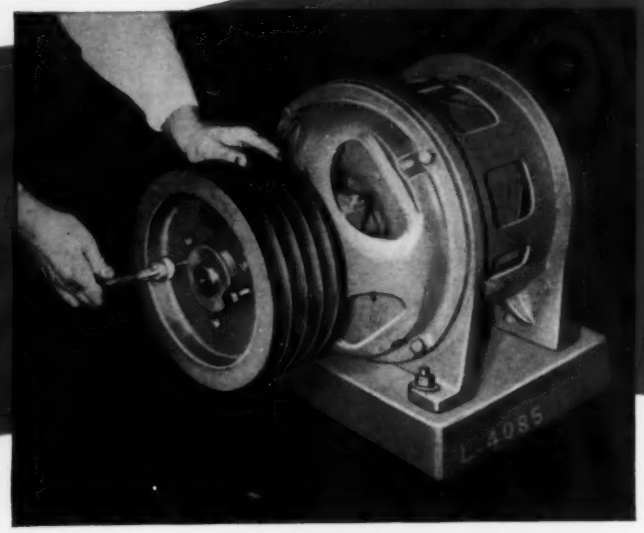

# Complete Rolling Mill Equipment

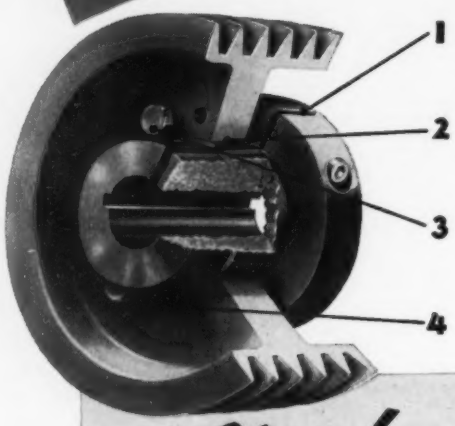
**FOUNDRY COMPANY** *Pittsburgh, Pa.*

# WORTHINGTON QD SHEAVES

QUICK DETACHABLE

EASY TO GET ON!
EASY TO GET OFF!






*Note!*

**1.** SPLIT HUB for easy mounting or removal from the shaft.

**2.** TAPERED FIT between split hub and rim for easy mounting or removal of rim from hub.

**3.** PULL-UP BOLTS which pull the rim onto tapered split hub for tapered friction drive assembly and positive press fit on the shaft.

**4.** TAPPED HOLES IN RIM for using pull-up bolts as jack screws to free the tapered friction fit when detaching the rim.

MULTI-V-DRIVE

MV2-11

## ——YET ALWAYS TIGHT ON THE SHAFT

"EASY TO GET ON! EASY TO GET OFF!—YET ALWAYS TIGHT ON THE SHAFT" is a fact that can be proved by one demonstration of the QD Sheave principle.

THE QD SHEAVE IS EASY TO INSTALL OR REMOVE because the QD patented design incorporates a split hub positioned on the shaft with a single cap screw. The rim is pulled up on a tapered fit with the hub by pull-up bolts.

THE QD SHEAVE IS ALWAYS TIGHT ON THE SHAFT because the pull-up bolts exert positive pressure on the tapered rim against the tapered split hub, providing a metal to metal fit.

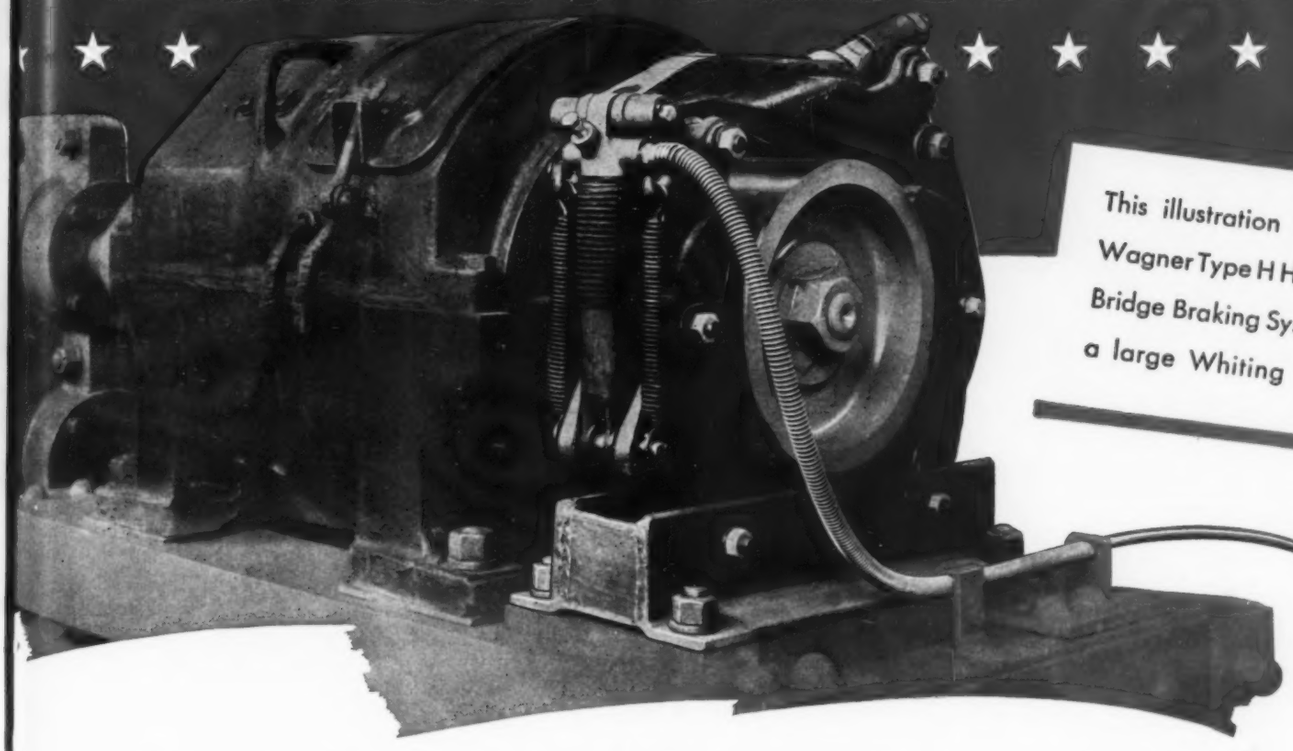
**Dealers everywhere are demonstrating to their customers the time-saving, labor-saving and material-saving advantages of the QD (Quick Detachable) SHEAVE.**

MEMBER MULTIPLE V-BELT DRIVE ASS'N

COMPLETE DRIVES — **WORTHINGTON MULTI-V-DRIVES** — SHEAVES OR BELTS ONLY

WORTHINGTON PUMP & MACHINERY CORPORATION • GENERAL OFFICES: HARRISON, N. J.

# WAGNER
## HYDRAULIC BRIDGE BRAKES



This illustration shows a Wagner Type H Hydraulic Bridge Braking System on a large Whiting Crane.

## *First Choice of Crane Manufacturers*

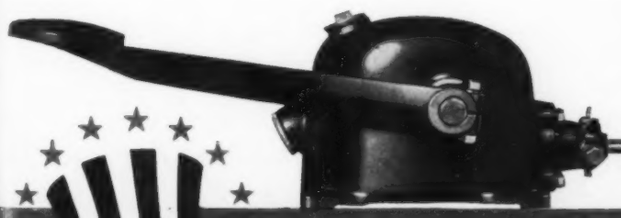
Many crane manufacturers today install Wagner Hydraulic Bridge Brakes on the cranes they manufacture because it has been found through actual experience that Wagner Hydraulic Bridge Brakes perform satisfactorily under even the most severe operating conditions.

The Wagner Hydraulic Bridge Braking System is complete in every detail. It comes to you ready to install, and includes everything necessary – brake assembly, brake wheel, master cylinder, wheel cylinder, copper tubing, flexible hose, brake fluid, and all fittings. The system is easy to install and any brake maintenance man can make the installation.

The Wagner Hydraulic Bridge Braking System assures positive braking action, smooth stopping, and controllable deceleration to all types of overhead and whirler cranes. It will pay you to investigate if you are planning on new cranes or conversion from mechanical brakes.

### FIELD ENGINEERING SERVICE

★ Wagner maintains 25 branch sales and service offices conveniently located throughout the United States. Each one of these branches is manned by trained field engineers who will be glad to assist you in solving your crane brake problems. ★



**Wagner Electric Corporation**
6400 Plymouth Avenue, Saint Louis, Mo., U.S.A.

SEND FOR BULLETIN IU-20

BRIDGE BRAKES • MOTORS • TRANSFORMERS

# *Better Bearing Results— Without Critical Metals!*

GATKE Moulded Fabric (Non-Metallic) Bearings are taking the sting out of critical metal shortages for countless manufacturers and users of equipment of all kinds.

These Modern Bearings are specially engineered for the application and made of different material combinations to meet various service requirements—a procedure that is made possible only by GATKE'S specialized experience and comprehensive manufacturing facilities.

GATKE Bearings are made in three types (1) for Water Lubrication, (2) for Grease or Oil Lubrication, and (3) for some Self-Lubricated Applications.

**YEARS before Bearing Metals became critical GATKE Moulded Fabric Bearings had proved themselves far superior to conventional Bearings.**

**Today, through GATKE experience, accumulated in years of specialized development, these Wonder Bearings are replacing metal bearings on all sorts of applications in all industries with countless benefits. They save critical metals and give much better results — greatly increased wear life — reduced maintenance time and expense — power saving.**

**The change-over is simple. GATKE Bearings are moulded to machined accuracy in all shapes and sizes for replacing metal bearings without machining.**

**Just send dimensional prints of bearing with load, running speed, lubrication, etc. for recommendations.**

*Other* **GATKE PRODUCTS**

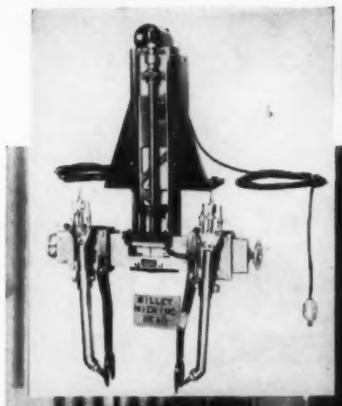
Brake Lining
Clutch Facings
Friction Blocks
Silent Gears
Pump Valves
Piston Rings
Sheet Packings

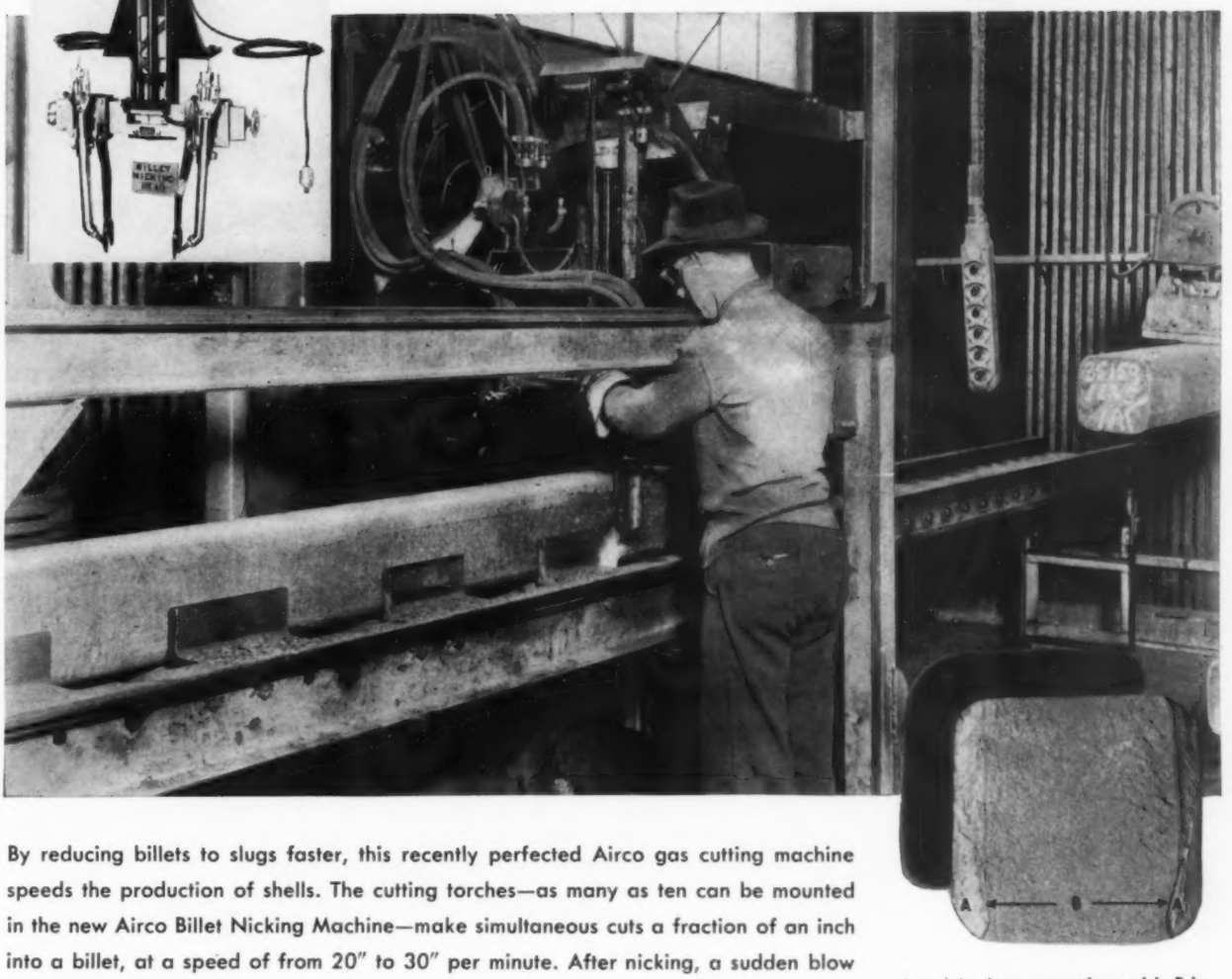
**GATKE CORPORATION • 228 N. LaSalle St., CHICAGO**

**Gatke MOULDED FABRIC Bearings**

**For Roll Necks, Universal Couplings, Spindle Carriers, Table Rolls, Cranes, Acid Resisting Service, and Other Tough Jobs.**

# BILLETS *to* BULLETS *faster!*





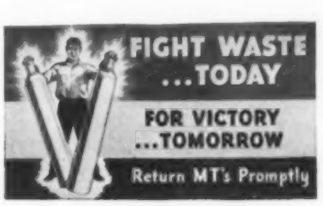



A and $A_1$ show areas of gas nick. B is section broken by hammer blow, after nicking.

By reducing billets to slugs faster, this recently perfected Airco gas cutting machine speeds the production of shells. The cutting torches—as many as ten can be mounted in the new Airco Billet Nicking Machine—make simultaneous cuts a fraction of an inch into a billet, at a speed of from 20" to 30" per minute. After nicking, a sudden blow produces a clean break.

This special flame cutting machine is another development made possible by the teamwork of Airco engineers and our customers'—each contributing their specialized knowledge towards one common objective.

Air Reduction's wartime policy is to help American industry do the tough job we all face. Our nationwide field engineering service and our research facilities are at your disposal to supply "know how" information on any problem involving the use of the oxyacetylene flame and the electric arc.




**Air Reduction**

*General Offices:*
60 EAST 42nd STREET, NEW YORK, N. Y.
IN TEXAS
MAGNOLIA-AIRCO GAS PRODUCTS CO.

AIRCO

WILSON

**OXYGEN IS PRODUCTION — *Don't Waste it!***

# CLARK "3C" DIRECT CURRENT CONTROL ON VAUGHN WIRE DRAWING MACHINES—

## VARIABLE VOLTAGE OR RHEOSTATIC

The War demand has greatly stimulated Wire Production for War purposes. "3C" Control, applied with Vaughn Wire Drawing Machinery, is helping to meet this increased demand.

CONTINUE TO ROLL WITH CLARK CONTROL

**THE CLARK CONTROLLER CO.**

1146 EAST 152ND ST. CLEVELAND, OHIO

# "Techni"
## PROCESS ROLLS

**Other Mackintosh-Hemphill Products:**

Rolling Machinery

Shape Straighteners

Strip Coilers

Shears

Levellers

Pinions

Special Equipment

Iron-Steel Castings

The NEW Abramsen Straightener

Improved Johnston Patented Corrugated Cinder Pots and Supports

Heavy Duty Engine Lathes

More tons and lower cost per ton rolled; less slippage; greater bite; better surface and resistance to fire cracking—these are the profit making advantages you get with "TECHNI" Process Blooming and Slabbing Mill Rolls. These extra qualities are made possible by the "TECHNI" Process, an exclusive development of Mackintosh-Hemphill, which regulates the quality and grain size of the rolls with as much exactness as the best modern steel practice regulates the quality of steel.

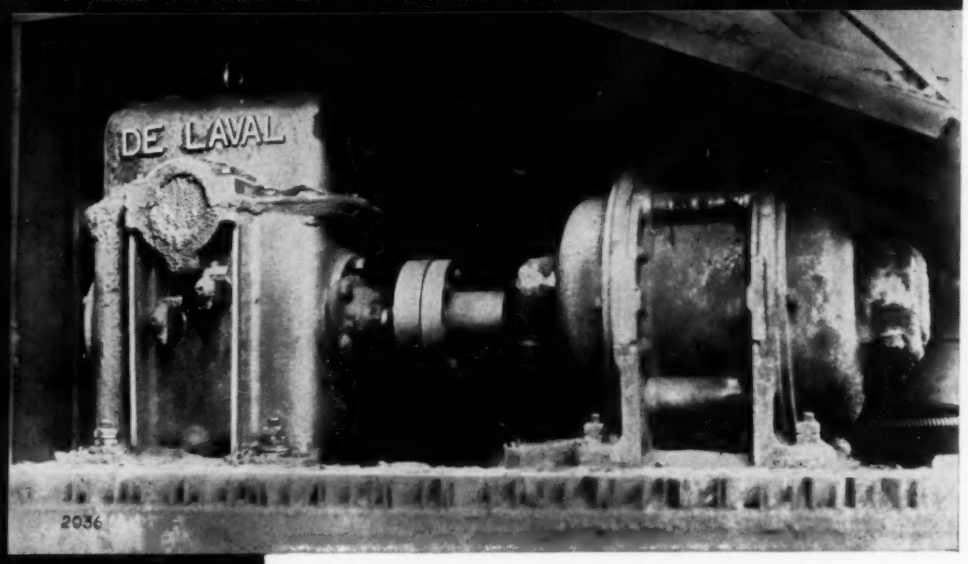
Make your next set of rolls "TECHNI" Process.

*Since 1803—Pioneers, Engineers and Builders*

MACKINTOSH-HEMPHILL COMPANY . . . Pittsburgh and Midland, Pennsylvania

FOR BLOOMING AND SLABBING MILLS

# for CONTINUOUS PRODUCTION




De Laval worm gear driving coal conveyor

Bottom drive

Top drive

Gear shaft vertical

Double reduction

Breakdowns in power transmission in 24-hour plants are eliminated where plant engineers specify the

## DE LAVAL WORM GEAR

for heavy duty drives, particularly in locations involving exposure to grit, dust and moisture.

The two moving parts of the gear run in a bath of oil and it is self-lubricating, requiring no attention beyond inspection of the level in the oil well at long intervals.

The unit does not throw grease or oil.

Safety guards are unnecessary, as the working parts are enclosed.

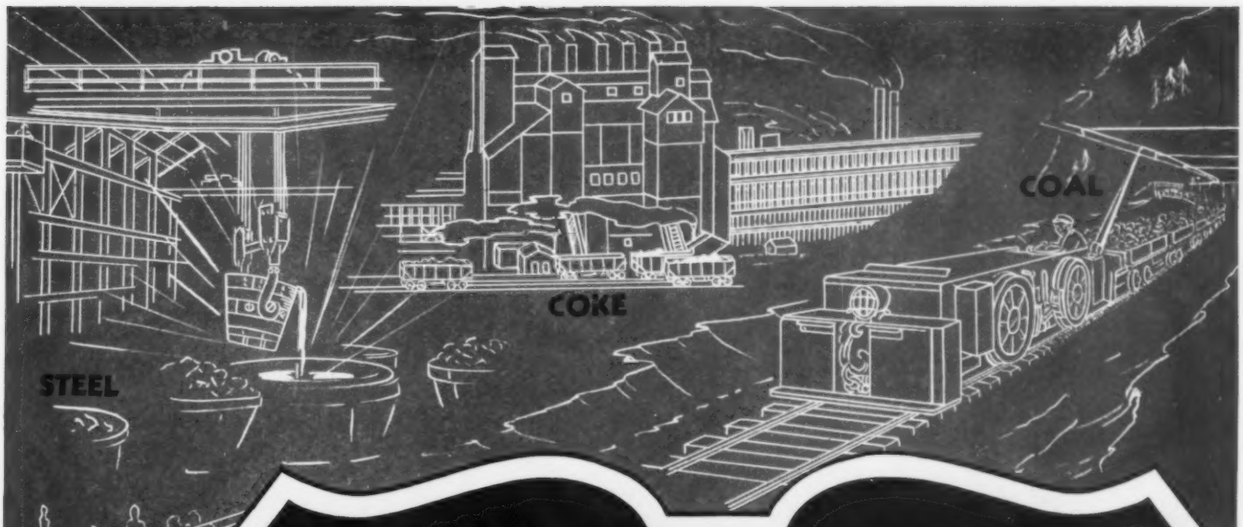
The efficiency is high, and improves with use.

The drive is smooth and quiet. It is also positive; there is no slippage, regardless of starting torque.

Describe conditions and ask for Publication W-1132.

**DE LAVAL WORM GEAR DIVISION**
of the De Laval Steam Turbine Co., Trenton, N. J.

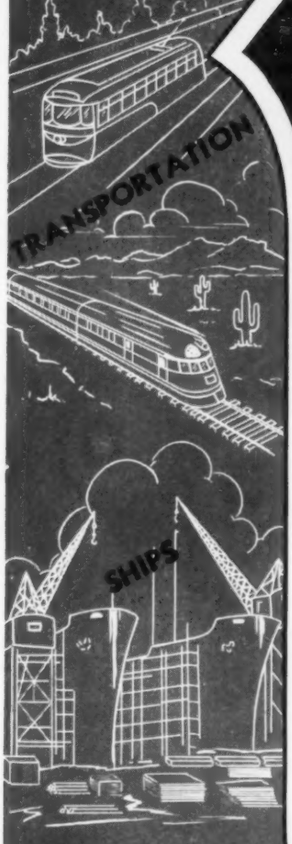
MANUFACTURERS OF TURBINES STEAM, HYDRAULIC PUMPS CENTRIFUGAL, PROPELLER, ROTARY DISPLACEMENT, MOTOR-MOUNTED, MIXED FLOW, CLOGLESS, SELF-PRIMING CENTRIFUGAL BLOWERS and COMPRESSORS, GEARS WORM, HELICAL and FLEXIBLE COUPLINGS



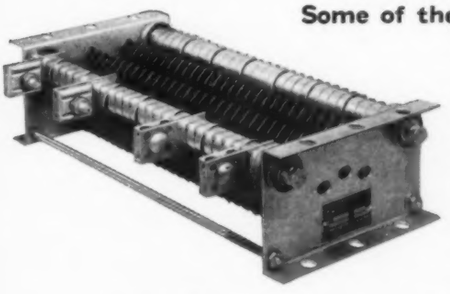

# P-G RESISTORS IN BASIC INDUSTRIES HELP OUR WAR PRODUCTION EFFORT

COAL, Coke, Steel, Transportation and Ships are necessities in continuous and increasing quantities to win the battle of supply, a victory that must be won at home, before the Axis can be whipped.

In all five, engineers specify "non-breakable" P-G Steel Grid Resistors as an aid in maintaining and increasing this vital production. There are good reasons for P-G "Trouble-free Service".




Some of them are:



- ★ ALL STEEL CONSTRUCTION
- ★ MICA INSULATION
- ★ RUGGED TERMINALS
- ★ PROVISION FOR EXPANSION
- ★ ADEQUATE VENTILATION
- ★ UNAFFECTED BY VIBRATION
- ★ MOISTURE RESISTANT
- ★ CORROSION PROTECTED

*"The Resistor you can Install and Forget"*

P-G

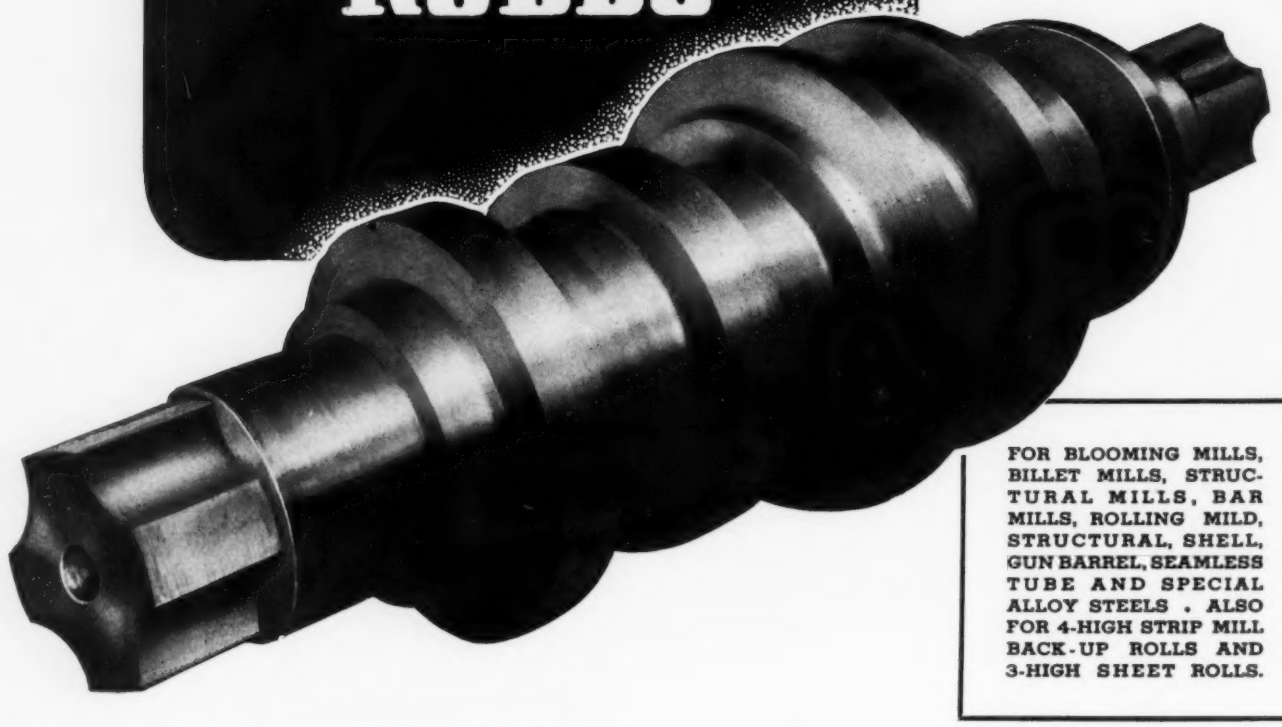
## THE POST-GLOVER ELECTRIC COMPANY

• ESTABLISHED 1892 •

221 WEST THIRD STREET, CINCINNATI, OHIO

Tailored to your needs

# BIRDSBORO "Special" ROLLS



FOR BLOOMING MILLS, BILLET MILLS, STRUCTURAL MILLS, BAR MILLS, ROLLING MILD, STRUCTURAL, SHELL, GUN BARREL, SEAMLESS TUBE AND SPECIAL ALLOY STEELS . ALSO FOR 4-HIGH STRIP MILL BACK-UP ROLLS AND 3-HIGH SHEET ROLLS.

• Solving *your* roll problems—not just those of the industry in general — is the job of Birdsboro *Individualized* Roll Service. If you want more tonnage, longer roll life — more "speed with accuracy" — it will pay you to consult Birdsboro *now.*

BIRDSBORO STEEL FOUNDRY AND MACHINE CO. • Birdsboro, Pennsylvania

BIRDSBORO ROLLS

# *"He was more than just a salesman"*

*"When he entered my office on his first call I thought he was just another salesman taking up my precious time. However, after I saw what he accomplished I told him to drop in again on his next trip. It was the service he rendered which won my confidence.*

*"Today, with time at a premium, engineers like myself are anxious to reduce production cycles to a minimum. That is precisely what he did.*

*"We were accustomed to treating our electrical units with four coats of insulating varnish which required 22 work hours for the complete cycle. This salesman suggested that I allow him to treat a few of our units in our plant using his treatment cycle. Naturally as there was nothing to lose, I told him to go ahead. The results were far beyond my expectations. I had the laboratory put those units on test. As they surpassed our requirements, I asked him what he had done.*

*"He told me he applied two coats of his insulating varnish and had baked the first coat six hours and the other eight hours. The remarkable feat is that his treating cycle afforded better protection and to top it off, he saved us eight hours in baking.*

*"You certainly know what time saved means today."*

Your case may be a little different but many engineers are faced with the problem of determining the proper type of varnish for treatment of their electrical units. This requires painstaking research, for varnish insulation and treatment which may prove very successful on one type of an electrical unit may be entirely unsatisfactory on another.

We maintain a fully equipped laboratory for those who are confronted with an insulating varnish problem. We are confident, no matter what your problem may be, that with our years of research and specialization in the field of insulating varnishes, we can help you.

There is no obligation entailed. Write and give us full particulars.

Dolph's

CHINALAK AND SYNTHITE Black and Clear Baking Varnishes
Red Coil Finishing Enamels
Black and Clear Air Drying Finishing Varnishes
Melting and Stator Compounds

**JOHN C. DOLPH CO.**

*Insulating Varnish Specialists*

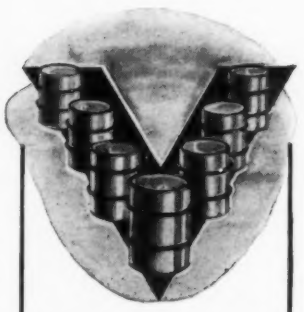
166A Emmett Street Newark, N. J.

## . . . . until they switched to Tycol Green Cast Grease

This manufacturer had been experiencing numerous difficulties with the grease previously used on his centrifugal boiler pumps and the bearings on his chain stokers. On the advice of a Tide Water engineer they switched to Tycol Green Cast Grease. Since then the nuisance of having to keep an eagle eye on the grease job has been eliminated. Now they just put in Tycol Green Cast Grease and forget it. One less item to worry about – the grease stays put and does an economical and dependable job of lubricating.

Tycol Green Cast Grease can effect economies in your plant, too, because this modern grease is made from a paraffine base cylinder oil combined with a minimum of soap. More oil – less soap – means better lubrication.

Let a Tide Water engineer show you where and how improved lubrication can step up production. Write the Tide Water Associated Oil Company, 17 Battery Place, New York, N. Y. Assistance is freely offered.



**DRUMS, DRUMS, DRUMS**

War needs make it extremely important that all empty drums be returned immediately.

Regional Offices: Boston, Philadelphia, Pittsburgh, Charlotte, N. C.

**TIDE WATER ASSOCIATED OIL COMPANY**

EASTERN DIVISION: 17 Battery Place, New York, N. Y.

MAKERS OF THE FAMOUS VEEDOL MOTOR OIL

INDUSTRIAL TYCOL OILS-GREASES

**TIDE WATER INDUSTRIAL LUBRICANTS**

THERE IS A COMPLETE LINE OF TYCOL LUBRICANTS SCIENTIFICALLY ENGINEERED FOR EVERY INDUSTRIAL USE

# Speeding to Victory on LINK-BELT CONVEYORS

★ ★ ★ ★ ★ ★ ★

## AMERICAN GENIUS FOR MASS PRODUCTION IS CONQUERING THE TIME ELEMENT

Complete Link-Belt anti-friction belt conveyor system handling coal from self-unloading lake vessels direct to plant or to storage piles or from storage to plant as desired. Link-Belt Speed-o-Matic cranes reclaim coal from storage and deliver it to traveling hoppers over belt conveyor.

Coils of rod are cooled, banded, and inspected, as they are handled on this Link-Belt overhead trolley conveyor which is equipped with mechanical loading and discharge mechanism. This type of conveyor has great possibilities in flexibility of arrangement, capacity and length.

● Production methods in this war have developed a new functionary: the expediter—one who clips minutes, hours or days from production schedules by speeding the movement of materials and products into and out of plants. Within the plants, from stage to stage of production, from machine to machine, as well as outside, Link-Belt conveyors are nipping minutes, from processes or intervals; bits of time that total up to huge aggregate savings, helping to bring true the production man's dream of "Plenty, On Time, and Right."

Link-Belt Company has long specialized in the engineering and manufacturing of practically every type of mechanical conveying equipment for all industries, and our engineers are ready to show you how to use efficient handling systems to save time and manpower and speed production.

Two lines of Link-Belt conveyors handling hot coils from two down-coilers. The coils are transferred to the storage conveyor shown in foreground. While traveling on this Link-Belt conveyor they are automatically weighed and cooled.

**LINK-BELT COMPANY**

Leading Manufacturer of Materials Handling and Mechanical Power Transmission Machinery
Chicago, Indianapolis, Philadelphia, Atlanta, Dallas, San Francisco, Toronto, Pittsburgh, Cleveland, Detroit
Offices, warehouses and distributors in principal cities

2038-B

**THROW YOUR SCRAP INTO THE FIGHT!**

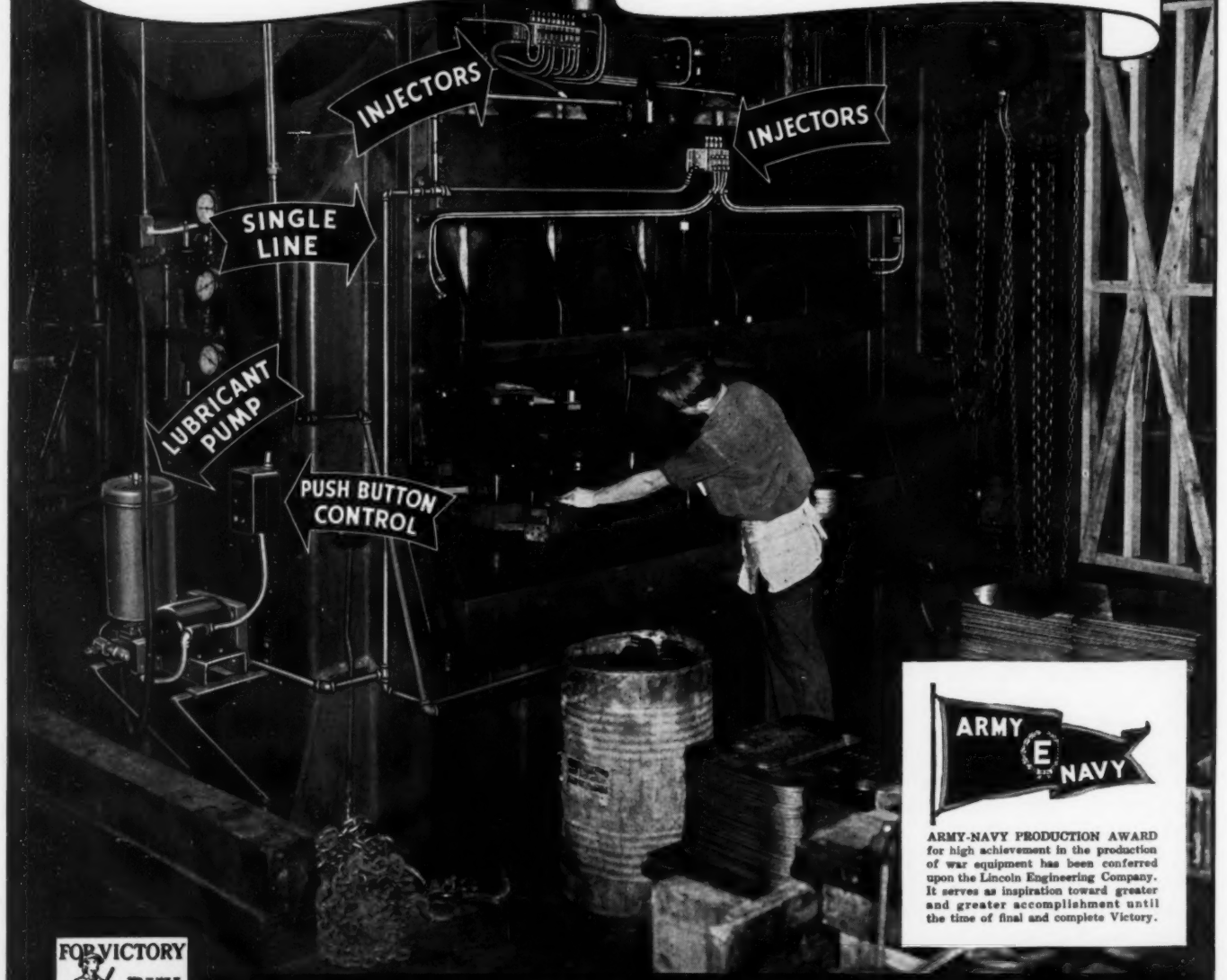
# LINCOLN CENTRO-MATIC LUBRICATING SYSTEMS

**cut down on bearing failures and prevent delays in producing war orders**

## Easily installed on new or old machines...Lubricate all bearings from a single source--quickly, economically

Basically all Lincoln Centro-Matic Systems are the same. A Centro-Matic System consists of a number of Centro-Matic Injectors—one for each bearing—and a hand operated or a power operated Centro-Matic Lubricant Pump. A power operated system can be semi-automatic or it can be full automatic. The injectors can be grouped in manifold or located separately at each bearing. In either arrangement only a single lubricant supply line is required. 142-17

***For details, please write for Bulletin 888***




ARMY E NAVY

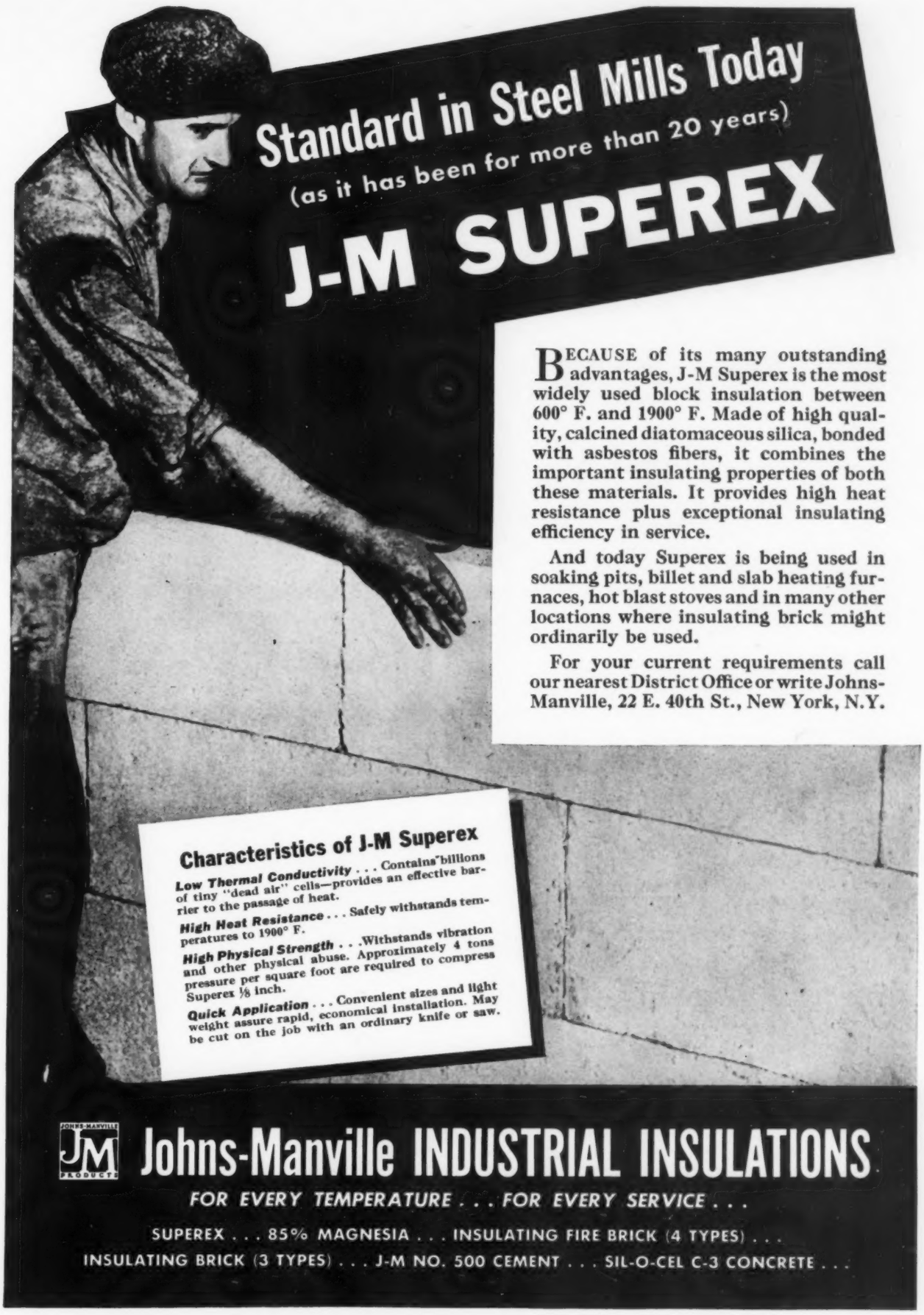
ARMY-NAVY PRODUCTION AWARD for high achievement in the production of war equipment has been conferred upon the Lincoln Engineering Company. It serves as inspiration toward greater and greater accomplishment until the time of final and complete Victory.

FOR VICTORY BUY UNITED STATES WAR BONDS AND STAMPS

## LINCOLN ENGINEERING COMPANY

*Pioneer Builders of Engineered Lubricating Equipment*

ST. LOUIS, MO., U. S. A.



# Standard in Steel Mills Today
(as it has been for more than 20 years)
# J-M SUPEREX

BECAUSE of its many outstanding advantages, J-M Superex is the most widely used block insulation between 600° F. and 1900° F. Made of high quality, calcined diatomaceous silica, bonded with asbestos fibers, it combines the important insulating properties of both these materials. It provides high heat resistance plus exceptional insulating efficiency in service.

And today Superex is being used in soaking pits, billet and slab heating furnaces, hot blast stoves and in many other locations where insulating brick might ordinarily be used.

For your current requirements call our nearest District Office or write Johns-Manville, 22 E. 40th St., New York, N.Y.

## Characteristics of J-M Superex

***Low Thermal Conductivity*** . . . Contains billions of tiny "dead air" cells—provides an effective barrier to the passage of heat.

***High Heat Resistance*** . . . Safely withstands temperatures to 1900° F.

***High Physical Strength*** . . . Withstands vibration and other physical abuse. Approximately 4 tons pressure per square foot are required to compress Superex ⅛ inch.

***Quick Application*** . . . Convenient sizes and light weight assure rapid, economical installation. May be cut on the job with an ordinary knife or saw.

JOHNS-MANVILLE JM PRODUCTS

## Johns-Manville INDUSTRIAL INSULATIONS

*FOR EVERY TEMPERATURE . . . FOR EVERY SERVICE . . .*

SUPEREX . . . 85% MAGNESIA . . . INSULATING FIRE BRICK (4 TYPES) . . .
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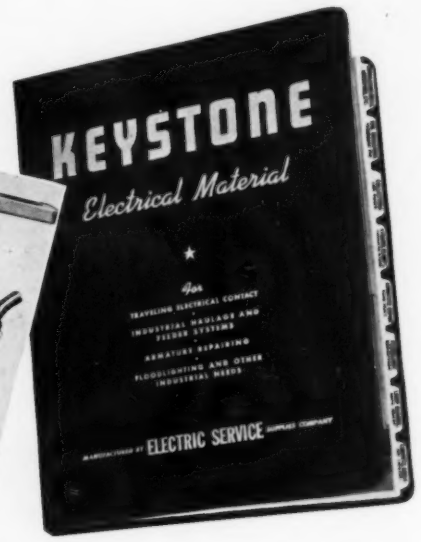
# Headquarters

## For Traveling Electrical Contact and Heavy Feeder System Materials

A complete line of contact rail material utilizing either rails, angles or wire as a conductor including numerous types of insulators for either under-running or over-running operation. You may also select from many types of current collectors including Junior, Universal and Pantagraph styles and contact rail shoes.

The Keystone line also includes numerous types of clamps and insulators for the insulation, suspension and dead-ending of heavy feeder cables.

These products are widely used in most large steel mills, being thoroughly proved in service. The complete catalog illustrated below will be very helpful to all interested in the construction or maintenance of cranes or feeder systems.

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17th & CAMBRIA STREETS • PHILADELPHIA • PA. • BRANCHES IN PRINCIPAL CITIES AND FOREIGN COUNTRIES

# Some Men Build Planes with a Bulldozer

While the American construction industry has been performing fabulous feats of building, prophets have been predicting that "next year," war building would be all done, and the construction industry would retire, deflated, to the sidelines.

In 1940, the lull was to come in Spring, 1941. Then it was to come in Winter, 1941-42. Then in Spring, 1942. But this industry forges on and on, running up buildings, cutting down time, breaking records.

Construction this year will probably reach twelve billions. That outstrips anything ever seen. But already, post-war planners figure that a twenty-three billion dollar construction year is not hard to foresee in peacetime years. Already the backlog of unbuilt homes, postponed commercial buildings, and delayed public improvements is running into billions.

Koppers is grateful that it has been able to contribute to the construction industry's records by manufacturing and supplying pressure-creosoted and salts-treated timber required for war factories, hangars, defense housing, piers and other construction.

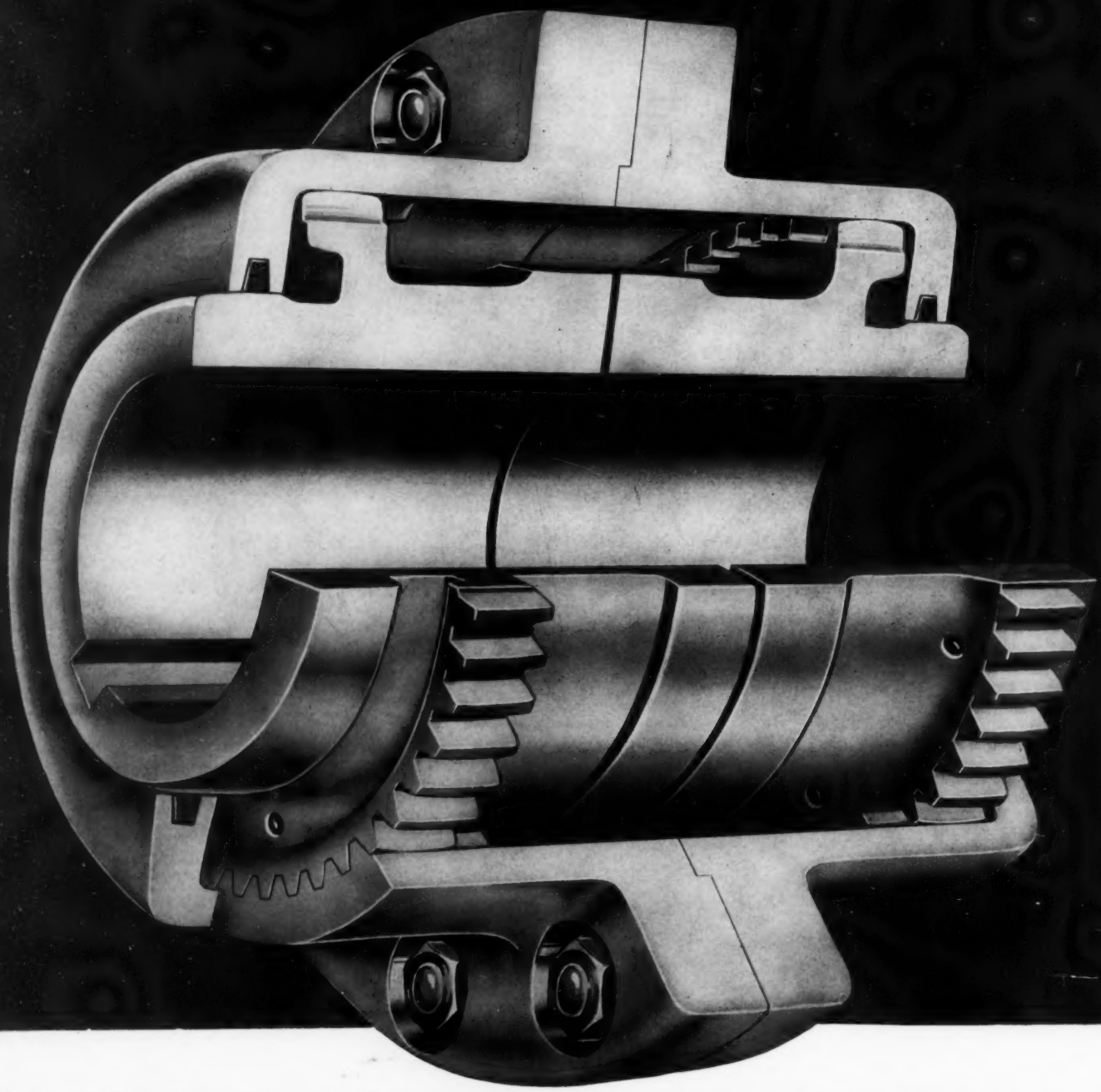
For one war factory roof alone, Koppers shipped 200 carloads of coal tar roofing. Koppers waterproofing has gone into ammunition igloos . . . important Koppers ingredients have gone into the plastics which bond the layers of plywoods now used in such volume . . . Koppers road tars have built access roads to war factories and army camps. These are but a few examples of peacetime products satisfying vital wartime needs. Koppers Company, Pittsburgh, Pa.

Buy United States
War Bonds and Stamps

**KOPPERS**

**THE INDUSTRY THAT SERVES ALL INDUSTRY**

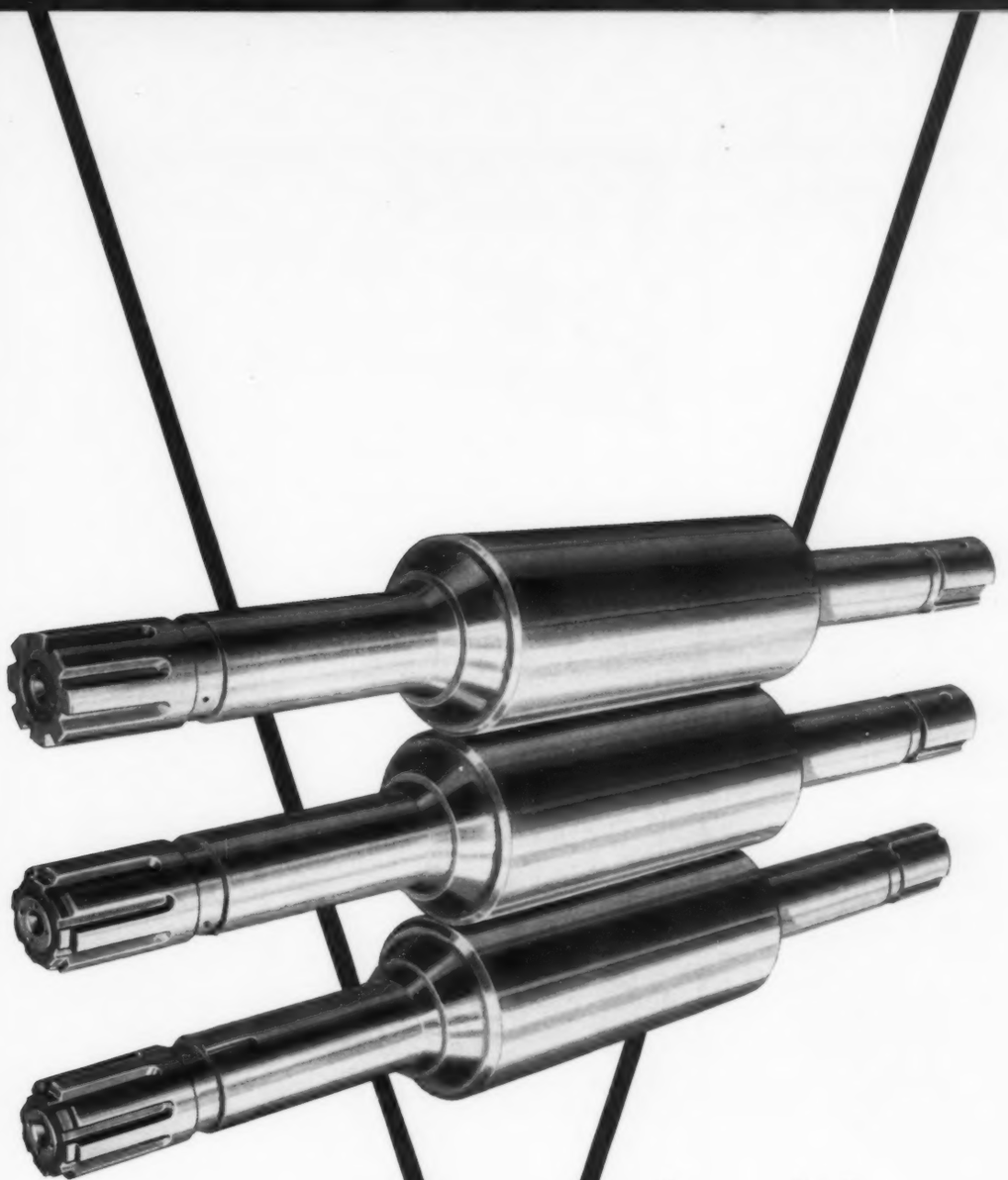
# POOLE



A COPY OF CATALOG GIVING FULL DESCRIPTION AND ENGINEERING DATA SENT UPON REQUEST.

# FLEXIBLE COUPLINGS

POOLE FOUNDRY & MACHINE COMPANY WOODBERRY, BALTIMORE, MD.



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1. **They give much longer life than new rolls.**
2. **Immediate delivery can be made (no waiting for raw material).**
3. **Vital steel alloys are conserved by re-use.**
4. **They cost but 25% to 75% of new rolls.**
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6. **Practically all of your cold working rolls are suitable for remaking or rehardening.**

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**THE TOOL STEEL GEAR & PINION COMPANY**

CINCINNATI, OHIO

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*Lubricated Plug*

## VALVES

STANDARD TYPE

NORDCO STEEL TYPE

EMCO-NORDSTROM TYPE

**The safest valves for war time service in steel plants, for oil, gas and chemical lines.**

*Keep upkeep down*

**MERCO NORDSTROM VALVE CO.**

*A Subsidary of Pittsburgh Equitable Meter Co.*

Main Office: Pittsburgh, Penna. Branches: Boston, Buffalo, Brooklyn, Chicago, Columbia, S. C.; Des Moines, Houston, Kansas City, Los Angeles, Memphis, New York City, Oakland, Philadelphia, San Francisco, Seattle, Tulsa.



# *Space Saving Possibilities*

*The* De Laval-

## IMO OIL PUMP

is exceedingly simple and compact.

Because of absence of valves, gears and reciprocating parts it can be directly coupled to run at motor or turbine speeds. There is no vibration or pulsation.

It handles any oil against any pressure.

Ask for Catalog I-95.

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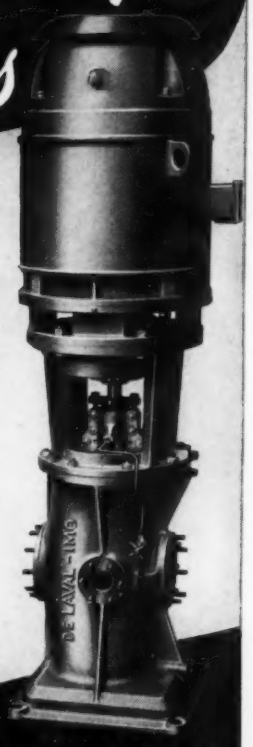
Lube oil service pump; 300 g.p.m. of 130 SSU oil from 10 in. Hg. suction to 50 lbs. per sq. in. at 1150 r.p.m.




IMO MOVES OIL

**IMO PUMP DIVISION**

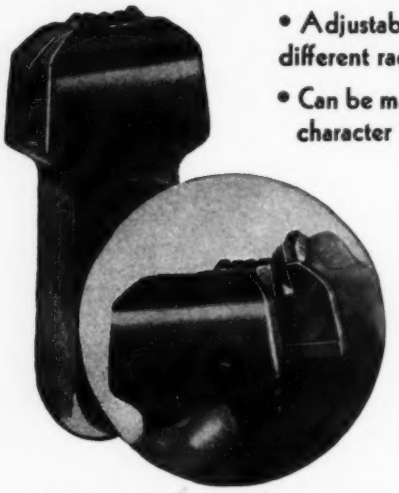
of the De Laval Steam Turbine Company

Trenton, New Jersey



## FOR STAMPING "ROUNDS" SAFETY

### WEDGE GRIP RADIUS HOLDER



- Adjustable for stamping different radii.
- Can be made for any size character 1/8" and up.
- SAFETY STEEL—construction insures against spalling and mushrooming.
- Ideal for stamping shells, round bars, axles, etc.
- Can furnish our BOX STYLE RADIUS HOLDER for hot marking of shell forgings and axles.

*Write for complete information.*

**M. E. CUNNINGHAM CO.**

105 E. CARSON ST. PITTSBURGH, PA.

*Conductors on both hi-lines and rural lines are A.C.S.R.*

Hi-lines supplying industry and rural lines carrying power to the farm front—there must be no stoppage in the flow of electricity which would cut off production of foodstuffs and supplies for our fighting forces.

The Government recognizes the vital part the power companies are playing in the country's war effort. Ruling P-46 permits you to obtain materials required for proper maintenance of power lines. No need to resort to makeshift devices.

You probably aren't seeing much today of the Alcoa engineers who called to tell you the virtues of A.C.S.R. They're very much on the job, however, expediting delivery of Aluminum Alloy products to war production plants. But they're available whenever you need their help in keeping hard-working power lines in service.

Consult with ALUMINUM COMPANY OF AMERICA, 2128 Gulf Building, Pittsburgh, Pennsylvania.

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A C S R

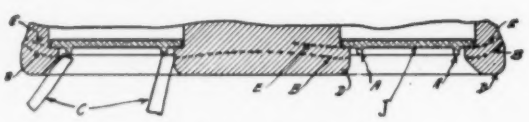
A·C·S·R *Aluminum Cable Steel Reinforced*

ON RURAL POWER LINES AND HI-LINES

# Ohio Magnet Outer Rings Seldom Break

**The bottom or wearing face of an Ohio Magnet presents a solid long lived surface to the work.**

**The annular rings on the manganese bottom plate prevent dangerous wear of steel pole shoes, so bottom plate cannot sag.** See cut below.



Note wear line B B B

**There are no holes or depressions to start wear or cracks.**

**These features result in**

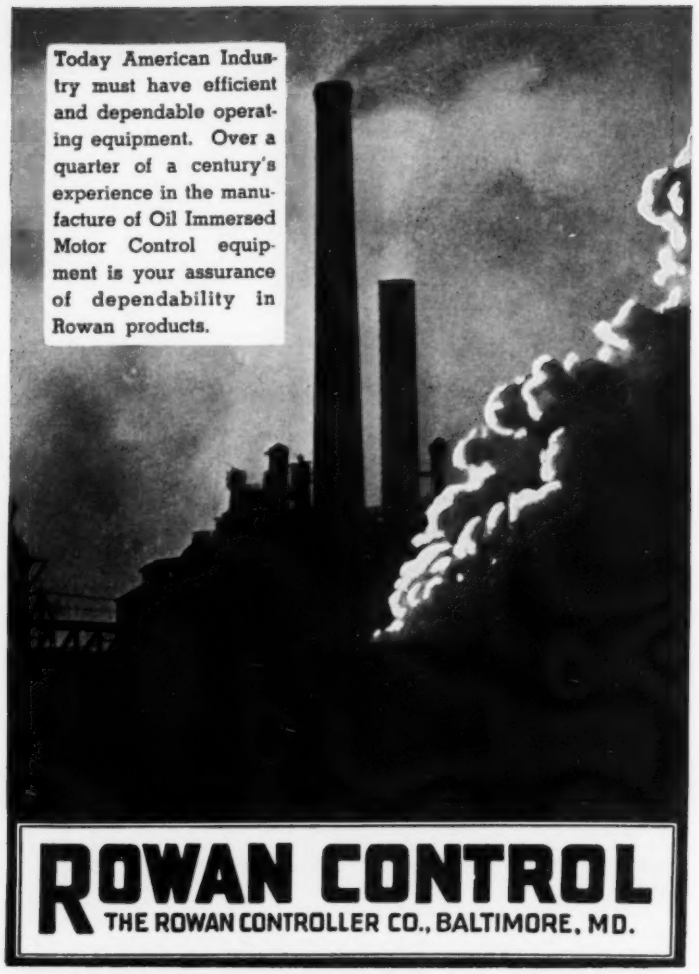
**LOW MAINTENANCE COST.**

OHIO reliable MAGNETS

**The OHIO Electric Mfg. Company**

**5907 Maurice Avenue**

**Cleveland · · Ohio**


Today American Industry must have efficient and dependable operating equipment. Over a quarter of a century's experience in the manufacture of Oil Immersed Motor Control equipment is your assurance of dependability in Rowan products.
ROWAN CONTROL
THE ROWAN CONTROLLER CO., BALTIMORE, MD.

# Stop Short Circuits
## Cut Motor Lubrication Cost

Short circuits cost considerable in lost production and expensive repairs, but money is wasted even before this happens. Every minute dripping oil is used it must be paid for twice over. You pay *once* for what's used. Once again for what's wasted.

NON-FLUID OIL is made so that it does not drip or leak, but stays in bearings lubricating till used up. It stays off windings, prevents short circuits and saves money by outlasting oil.

Used successfully in leading iron and steel mills. Send for instructive bulletins.

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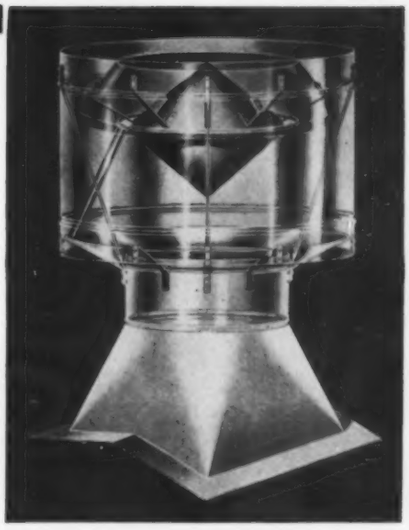
IN U.S. PAT. OFFICE & FOREIGN COUNTRIES

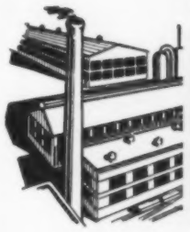
MODERN STEEL MILL LUBRICANT

*Better Lubrication at Less Cost per Month*



*Free Flow*
*Gravity*





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## VENTILATORS

## Fight Inertia With Fresh Air

There is a tonic effect in fresh pure air obtainable in no other way. Equip your mill with Burt Ventilators and your workers will respond to the vitalizing influence of improved ventilation, and the result will be fewer accidents, less spoilage and increased production.

The Free-Flow Gravity Ventilator and its companion units, Free-Flow Fan and Monovent Continuous Ridge Ventilator, give you every type needed to produce efficient, economical trouble-free ventilation. Write for detailed data and job references.

**THE BURT MFG. CO.**
ROOF VENTILATORS • OIL FILTERS
EXHAUST HEADS
950 SOUTH HIGH STREET AKRON, OHIO

SEND FOR CATALOGS
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Burt Engineers are glad to help on plans

When Shifts Run

'ROUND THE CLOCK,

Shift to

# ROLLWAY

## RIGHT-ANGLED LOADING

for

BETTER BEARING SERVICE

● The load which can be safely applied to a bearing depends more on *how long* and *at what speeds* the load is carried than it does on the crushing strength of the metals. That's why today's full-speed, 'round-the-clock operation definitely calls for the higher service factors provided by Rollway's right-angled loading of solid-cylindrical roller bearings.

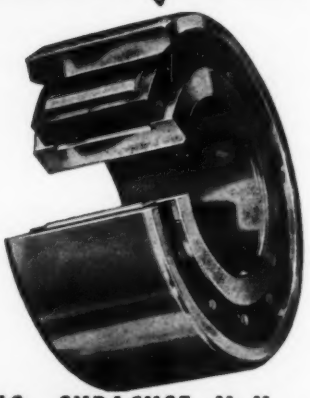
*Here's what it means:* Rollway splits every load into its two simplest components of pure radial and pure thrust. It carries each of these components at right angles to the axis of solid, cylindrical rollers. Oblique loading is eliminated. Sliding friction is reduced to the vanishing point. And a more compact bearing assembly with more massive rollers of uniform cross-section is the result. You reap the benefits in longer bearing life, higher machine speeds, less down-time and less service attention.

★ Send us your plans today for free engineering analysis and bearing recommendations. Most applications require only American standard metric dimensions and tolerances that need no costly extra tooling or different machine set-ups.

TYPE MCS DOUBLE WIDTH RADIAL, interchangeable with standard double-width bearings made to S.A.E. dimensions.

TYPE SDT DOUBLE ACTING THRUST for slow-speed service or for higher speeds where the direction of thrust is not reversed frequently or at high speeds.

**REMEMBER**—you can usually change over from other bearings to Rollway's of higher load capacities without increasing boundary dimensions.



ROLLWAY BEARING COMPANY, INC., SYRACUSE, N. Y.

BUILDING HEAVY-DUTY BEARINGS SINCE 1908 — BEARINGS

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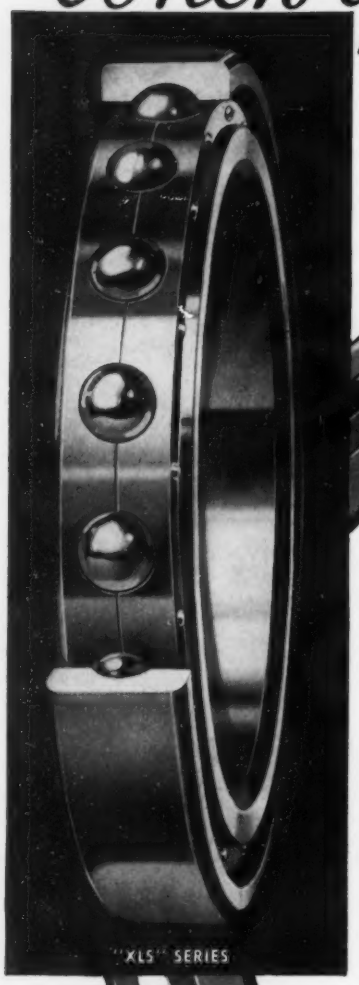
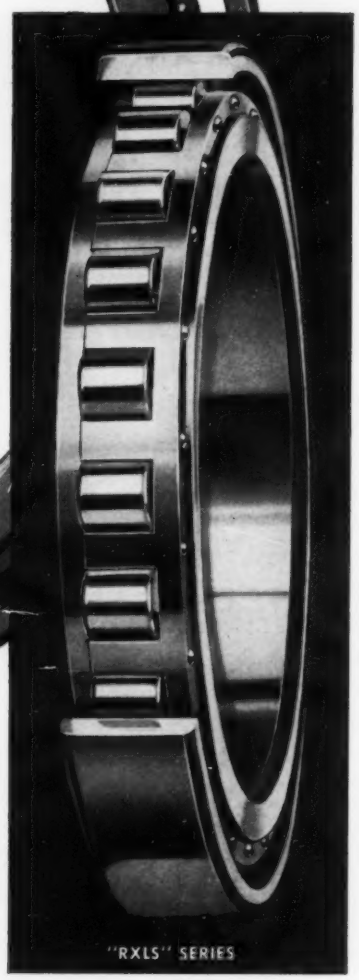
# *When You're Cramped for Space*

## USE THESE VERY LIGHT INCH SERIES BEARINGS






HAVING bores abnormally large, as compared with the outside diameter, they offer definite advantages under certain conditions found in machine design. You may have them in several different types, *affording compactness, light weight, and greater latitude in your design.*

There are several lines of very light type ball bearings, which include the "S" starting at 1/8" bore, and the "XLS" starting at 1 3/8" bore, running up to a maximum of 21" bore and 28" outside diameter. And in very light type roller bearings, there is the "RXLS" Series, paralleling the "XLS" in size range.

Why not let our engineers tell you more about these Very Light Precision Bearings? Write for the Catalog.

"NORMA-HOFFMANN"

PRECISION BALL, ROLLER AND THRUST BEARINGS

NORMA-HOFFMANN BEARINGS CORP'N.—STAMFORD, CONN., U. S. A.

# CRITICAL METALS SAVED

## *in Bus Structures*

**THE ENGINEERING INVOLVED** in correct design of bus structures has not received much emphasis in the literature of electrical development, despite the fact that engineering of a very exact nature is required.

However, when critical metals must be conserved as in this period of industrial expansion for war, nothing but the soundest engineering can provide designs capable of meeting all requirements including the saving of materials.

Portion of 23KV bus for a big hydro station, with sealed separate housings to provide phase isolation, shown partially assembled at the I-T-E plant.

The part that I-T-E has played in bus design is an interesting chapter in the story of modern developments in electrical practice. A booklet recently published, written by William Deans, Chief Engineer for I-T-E, discusses newly recognized electrical and mechanical factors in the design of current-carrying members and supporing structures, enclosed or open.

A copy of William Deans' booklet, twenty-four pages with illustrations and diagrams, will be sent upon request. The title is "Electrical Buses and Bus Structures", Bulletin 4211.

**I-T-E**

**AIR SWITCHGEAR**

IMMERSED IN AIR — ENCASED IN STEEL

The Army-Navy "E" for Production Excellence

**CIRCUIT BREAKER CO., PHILADELPHIA, PA.**

NOW... Listed by
Underwriters' Laboratories, Inc. for

# COAL DUST..COKE DUST CARBON BLACK

Another G-E FIRST in Motors For Hazardous Places

## New totally enclosed motors that meet Class II, Group F, combustible-dust hazards

As a part of its full line of motors for hazardous locations, General Electric can now supply motors specifically listed by the Underwriters' Laboratories to meet the dangers of combustible dusts included in Class II, Group F, of the National Electrical Code. Polyphase induction motors of this construction are available from 1 to 75 hp, single-phase types to 10 hp, direct-current types to 30 hp. Vertical motors and gear-motors are also included.

Dust-tight joints, including accurately rabbetted end-shield fits, plus a labyrinth seal and close-clearance bearing lips along the shaft, exclude dust from winding and bearings. External operating temperature at permissible overloads is well below the ignition point of the specified dusts. A one-piece, nonsparking fan (for fan-cooled sizes) assures effective cooling. Easy lubrication and servicing features are part of the well-planned design. For complete details, call or write your local G-E office. *General Electric, Schenectady, N. Y.*

BUILDER OF TRI/CLAD MOTORS
REG. U.S. PAT. OFF.

GENERAL ELECTRIC

TDG-185-N090

METAL DUST . . . ACETONE
TOLUOL . . . GASOLINE
COAL DUST...GRAIN DUST

**Name your hazard—this family can meet it**

No single enclosed or explosion-proof motor is recommended for all types of hazardous service. General Electric has pioneered in producing a family of motors to meet the dangers of specific gases, vapors, liquids, and dusts. For some hazards, only G-E motors are listed by Underwriters' Laboratories, Inc. Our engineering staff can help you pick the *right* motor, control, and other auxiliary equipment for uninterrupted war production.

The Navy "E", for Excellence, has been awarded to 92,700 General Electric employees in six plants manufacturing naval equipment